AFWAL-TR-82-2049

ADVANCED HIGH-POWER GENERATOR FOR AIRBORNE APPLICATIONS

AiResearch Manufacturing Company
A Division of The Garrett Corporation
2525 West 190th Street
Torrance, California 90509

June 1983

Interim Report for Period March 1981 - February 1982

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the work accomplished through Phase II of a four-phase program to design and build the stator and housing for a 5-Mw generator and test the complete 5-Mw generator. The PM rotor for this stator and housing is being built under a separate AF companion contract. This work is part of an Air Force exploratory program for high-power airborne electrical power supply technology. Phases I and II encompassed a 10-month period from April 1981 to January 1982.

In Phase I, a lightweight, high-power density stator/housing was designed and optimized with computer model BIGMAG for integration with a permanent magnet rotor into a 5-Mw alternator with a specific weight of 0.1 lb/kw or less.

Components with potential for significant weight reduction were identified for testing in Phase II. Among these critical components are a novel liquid-cooling scheme for the stator and an elastomer bore seal. Fabrication drawings were prepared for all individual parts of the stator and housing along with a detailed fabrication plan. A plan for testing the complete 5-Mw generator under full-load conditions at the AF Compressor Research Facility also was prepared. Fabrication and testing will be done in Phases III and IV, respectively.

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1. INTRODUCTION

This report describes work performed during Phase II of the stator/housing program for a 5-Mw permanent magnet generator currently being built under the Advanced High Power Generator Program, Contract F33615-80-C-2075, sponsored by the Powers System Branch, Aerospace Power Division, of the Aeropropulsion Laboratory at Wright-Patterson Air Force Base.

At Wright Patterson, the program is under the technical direction of Paul R. Bertheaud, and Capt. Rex Schlicher. At AiResearch, Fred B. McCarty is principal investigator, Frank E. Echolds is project engineer, and Andrew R. Druzsba is program manager.

As specified in Air Force CDRL 4, the report contains results of the critical component tests, a review of the design leading to a fabrication plan and long lead hardware definition, a no load test plan and a load test plan. All items presented require Air Force approval except the load test plan which was approved during a previous submittal.

2. CRITICAL COMPONENT TESTS

Critical component tests of the stator housing include the following:

Bore seal

Adhesives

Hairpin winding fabrication

Conductor impregnation and leach-out test

Conductor terminal fabrication

Conductor flow tests

2.1 VITON RUBBER BORE SEAL

A Viton rubber bore seal is used to exclude stator cooling fluid from the rotor cavity. It was estimated during the early part of the rotor program (F33615-76-C-2168) that a conventional type seal made of aluminum oxide would be 2 to 3 times as thick as the 0.020 thick Viton rubber bore seal that has been designed for use on the 5 MW alternator. A thin bore seal is highly desirable because it allows the air gap between rotor and stator to be as small as possible, thereby improving machine performance.

The Viton rubber bore seal is fabricated by repeatedly dipping a cylindrical tool into a container of liquid Viton. The result of this process is shown in Figure 2-1. After the Viton has air dryed, air pressure is applied to the inside of the tool, forcing the cured Viton away from the tool surface as shown in Figure 2-2. The bore seal is then ready to be coated with adhesive and installed in the stator bore. Air pressure is applied to force the seal against the stator bore until the adhesive dries.

The fabrication details of the full size bore seal are shown on Drawing 500421. Final installation of the seal into the stator housing is described in Drawing 500400.

This concept is considered to be developed well enough to be included in the final design without further component testing beyond what was done in the rotor program critical component phase and described in technical report AFWAL-TR-80-2130.

2.2 ADHESIVES

A number of different adhesives are used in the stator/housing that come

TABLE 2-1

ADHESIVE COMPATIBILITY TEST RESULTS

	Bonded Materials	Adhesive	Application
1.	Nomex - Nomex	PLV 2000	Matrix conductor insulator
2.	Silicon steel-silicon steel	Cycleweld	Stator stack
3.	Viton rubber - G10 epoxy glass	PLV 2000	Bore seal end support

Test Exposures	Bonded Materials		
	1	2	3
Methylene chloride 4 hrs, rm. temp.	Disolved bond	No effect	No effect
Air (baseline) 96 hrs, 350°F	No effect	No effect	No effect
Coolanol 25 96 hrs, 350°F	No effect	No effect	No effect
DC 200 96 hrs, 350°F	No effect	No effect	No effect

PLV 2000 is a Viton rubber based adhesive

Cycleweld is a nitrile phenolic adhesive

into contact with potentially reactive fluids. Sample testing was done during Phase II to determine what reaction, if any, takes place between the important adhesives used in the stator and three different fluids. The results of this testing are shown in Table 2-1. All of the bonded materials retained their strength after being exposed to the various fluids at temperature with the exception of the Nomex-Nomex bonded with PLV2000. This bond was completely degraded when exposed to the methylene chloride at room temperature for 4 hours. The Nomex to Nomex bond is formed in the process of fabricating the matrix conductor insulating jacket. Three sides of the jacket are formed in the winding fixture, the wire strands are layed in place, and the jacket is closed by folding over opposite sides of the Nomex and bonding with PLV2000. This bond is only required to hold until the conductors are inserted in the stator stack, after which they are held closed by the tightness of fit in the slot. Methylene chloride is flushed through the conductor to leach out the winding impregnant after this fit is accomplished.

2.3 HAIRPIN WINDING FABRICATION

The stator of the 5 MW generator incorporates hair pin windings, each terminating in specially designed terminals. The windings are formed from a multi strand conductor comprising 36 strands of #26 A.W.G. magnet wire bonded together with an adhesive and jacketed with Nomex insulation. After the hair pin is formed and the conductor is installed in the stator or the test fixture, the adhesive is leached out with methylene chloride.

Fabrication of the hair pin winding was a major portion of the Phase II development and testing effort. The winding was fabricated in the fixture shown in Drawing 500434. The fixture has the dimensions and special features to fabricate windings that will fit the final stator and the test fixture.

Before use of the final hairpin winding fixture, tests (experimental fabrication) were conducted on a prototype fixture to develop fabrication methods. Views of the conductor feeder used and the prototype winding fixture are shown in Figures 2-3 and 2-4. The prototype was used to fabricate the first hair pin conductors. In the fabrication, the 36-strand conductor was wrapped four-in-hand using adjustable tension blocks to assure equal tension in each strand, and a swivel guide was used to assure the proper sequencing and guiding of each strand. After measurement to verify proper dimensions the assembled conductor was sprayed and wiped to apply the adhesive (wiping produced the best results, and schemes to mechanize the procedure are being investigated).

The final hairpin winding fixture is shown in Figures 2-5 and 2-6. Figure 2-5 shows the winding fixture with the side plates attached, capturing a fully-bonded, 36-strand conductor impregnated with the stiffening cohesive agent VPE-5571, and Figure 2-6 shows the hairpin or knuckle end of the winding as wound and inpregnated in the winding fixture.

Using the completed fixture, conductors were fabricated for the ensuing tests. Figures 2-7, 2-8, 2-9, 2-10 and 2-11 show the completed conductor. Figure 2-7 is an overall view of the hairpin. Figure 2-8 shows the coolant hole in the Nomex insulation jacket. Figure 2-9 depicts the lead extensions for terminating the conductors. Figure 2-10 shows the hairpin winding knuckle and Figure 2-11 shows the cross section of a conductor. Figures 2-12 and 2-13 are views of the hairpin winding showing the terminals attached for test.

The bending qualities which make for a useable conductor were demonstrated during specific bending and forming experimentation and by use of the conductors in flow and other test setups. Work to improve conductor fabrication technique is continuing. These include precut, preformed insulators to achieve a more accurate conductor matrix and facilitate conductor manufacture. For example a special punch was designed to form cooling holes in the conductor insulation. Figure 2-14 shows the tool designed to punch holes in the cooling jacket, and Figure 2-15 shows the punched conductor as installed in the coolant test fixture. Face dimensions of the punch are 0.060 by 0.100 inch.

2.4 CONDUCTOR MATRIX IMPREGNATION AND LEACH-OUT TEST

To develop techniques for leaching out the conductors, two sample conductors 16-in. long were fabricated. They simulated the actual stator configuration with top and bottom coil sides, and proper oil passages in the insulation jackets were used. The bonding impregnant was successfully leached out of the conductors, AiResearch Memo 19318-45609-019 detailing the technique is included as Exhibit A.

2.5 CONDUCTOR TERMINAL FABRICATION

Conductor terminals were fabricated for use in the flow test and the final stator. The assembly is designed to hold pressure, provide dielectric capability, and accommodate thermal expansion. The design utilizes double O-rings, Nema grade C11 insulator (machined from spiral wrapped stock for coolant seepage protection) and a high-conductivity, zirconium and copper terminal element. These components are shown in Figure 2-16.

2.6 FLOW TESTING

Flow testing was conducted in the test rig shown in Drawings 94-38-0434 and LSK 17367. Figures 2-17, 2-18 and 2-19 show the test fixture unassembled, a closeup of the coolant relief at the conductor inlet, and the assembled components. Figures 2-20, 2-21 and 2-22 are various views of the flow test setup. An important part of setting up for the flow test was insertion of the hairpin into the test fixture, a function verification of the hairpin winding dimensional and bending characteristics. Figure 2-23 shows the conductor in the test setup. Figure 2-24 shows the crimped ends of the conductor in the test setup. Prior to installation, the ends of the conductor strands were dipped in MeCl solvent to remove the forming adhesive and the insulating enamel was stripped from the strands. End-lacing of the Nomex insulation jackets was provided so that coolant oil would enter the conductor matrix at the end of the insulation jacket (see Figure 2-25). The figure also shows the thermocouple installation for the tests.

For the tests flow meters were installed to measure the flow in each section of the conductor and the differential pressure across each inlet-to-outlet was measured. Oil viscosity measurements were made at various temperatures.

Temperature °F	Viscosity, CV
70	2.18
100	1.73
130	1.45
150	1.25

Resistances of the conductor and the insulation were measured. At 20°C conductor reactance was 0.00732Ω (within 1 percent of the calculated value). Insulation resistance measured at ambient temperature and 500 vdc was $150 \times 10^9 \Omega$ without cooling oil and $3 \times 10^{12} \Omega$ with cooling oil.

Initial flow testing yielded extremely low pressures and high flows as compared to those measured during previous conductor segment tests.*

Section No.	Flow, gpm	Delta Pressure Across Section, psid
1-2	0.0220	10.89
2-3	0.0220	10.60
3-4	0.0220	11.60
4-5	0.0220	14.79

Coolant flow was then adjusted to occur in all sections simultaneously as in the final stator configuration. The following results were obtained.

Section No.	Flow, gpm	Delta Pressure Across Section, psid
1-2	0.0227	10.65
2-3 } Common inlet	0.0432	10.29
3-4 } Common inlet		10.60
4-5	0.0226	15.90

Section 4-5 required a greater pressure than other sections; subsequent back flushing and retesting revealed improper leach-out of the conductor. The conductor was replaced and a more extensive leach-out is being performed at the time of this writing. Uniform coolant flow through each stator section and each conductor must be maintained in order to prevent the formation of local hot spots and possible conductor burn out. This prelimenary testing illustrates the effect of incomplete leach out on coolant flow. Once a completely leached out conductor is fabricated, as evidenced by equal section flows, testing at current density will begin.

*See AFWAL-TR-80-2130 for details.

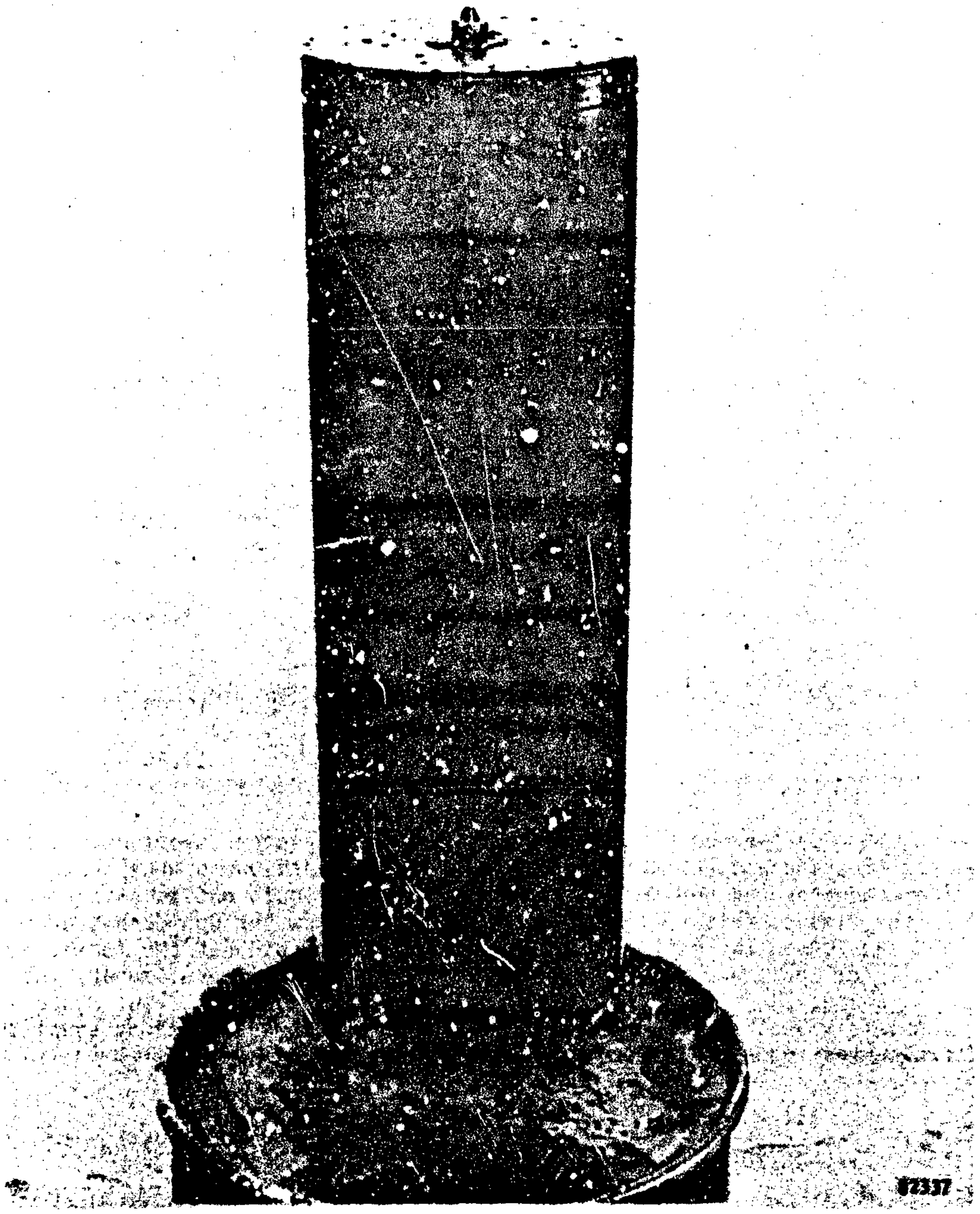

Figure 2-1. Bore Seal Tool Coated With Viton

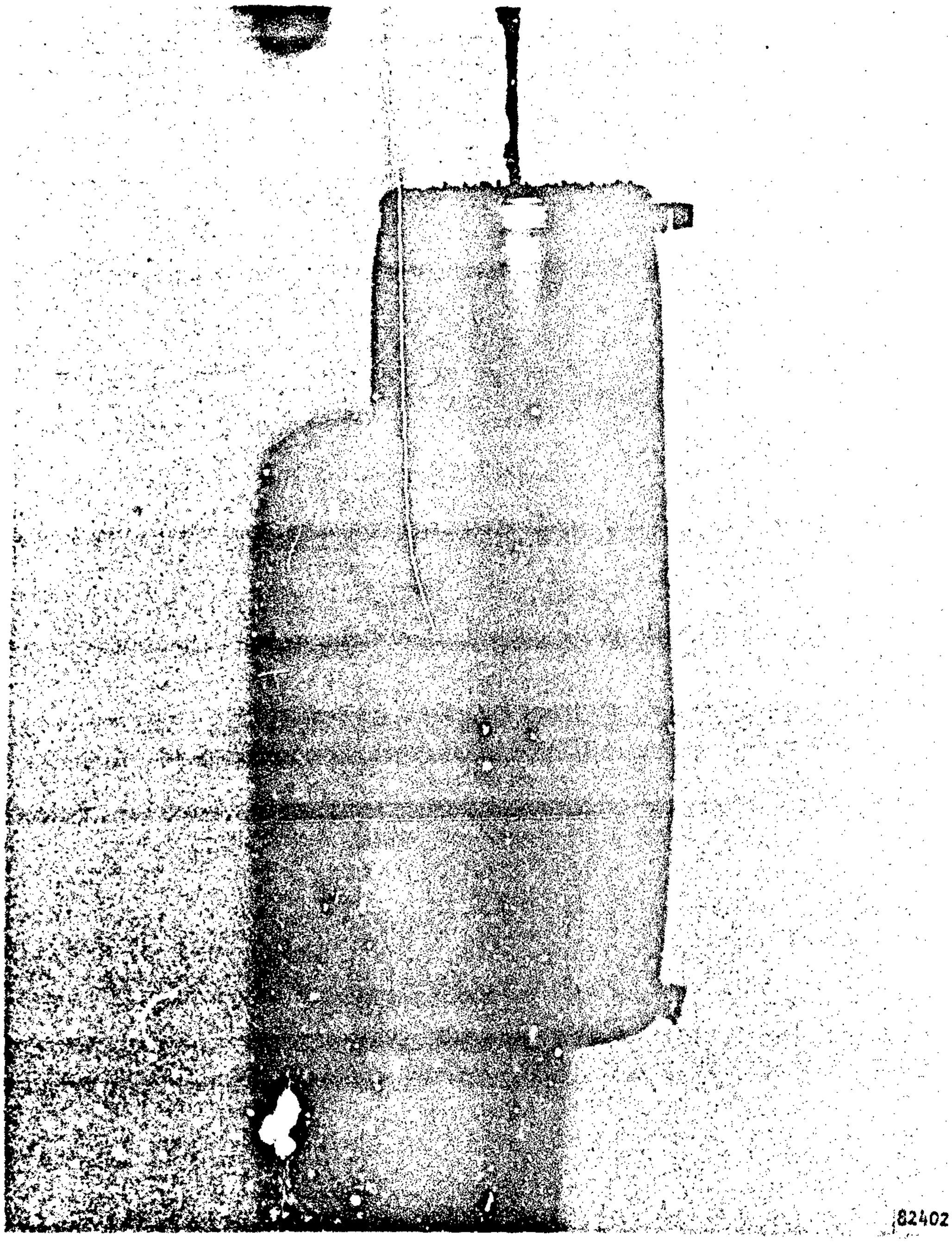

Figure 2-2. Inflated Bore Seal on Tool

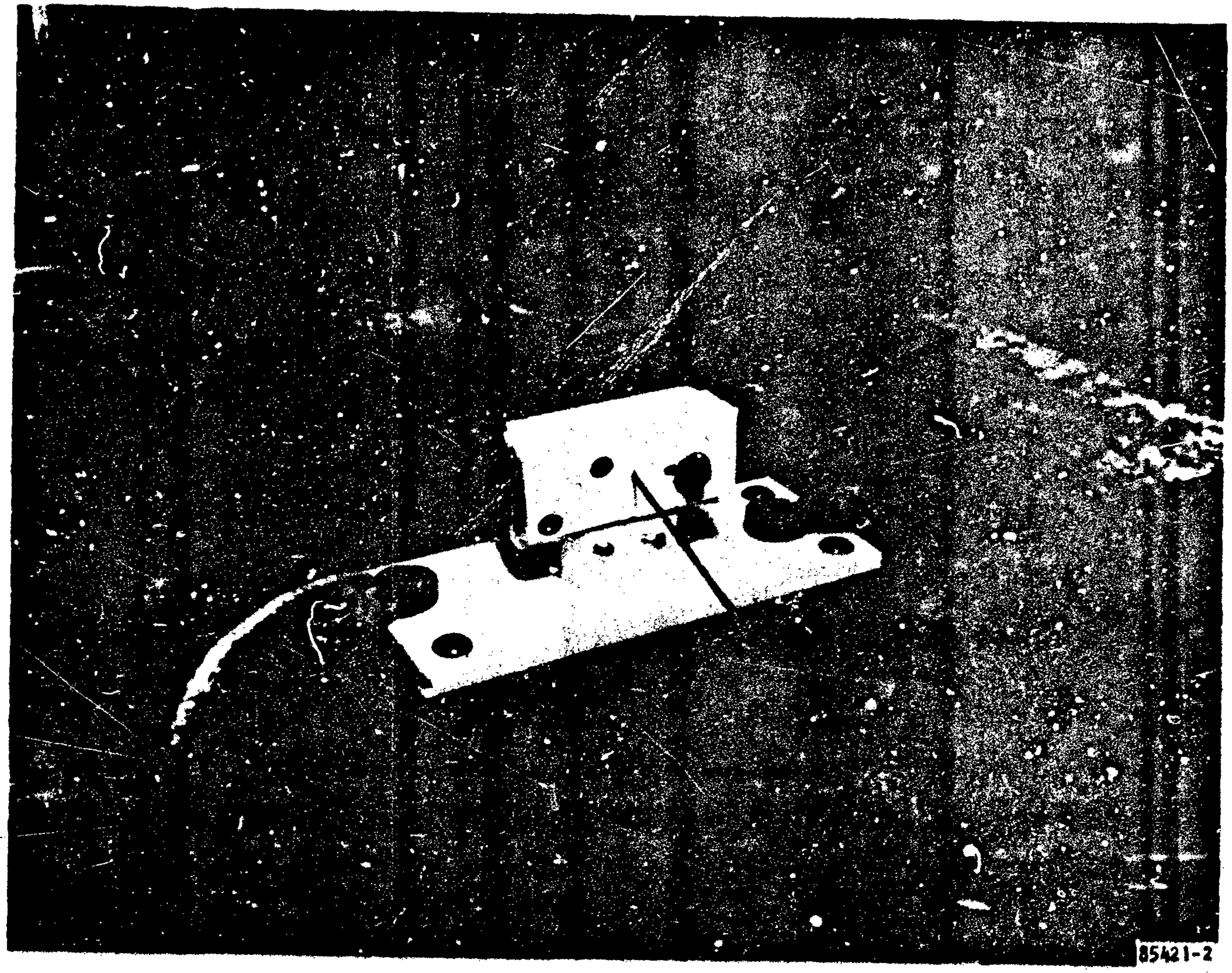

Figure 2-3. Conductor Feeder

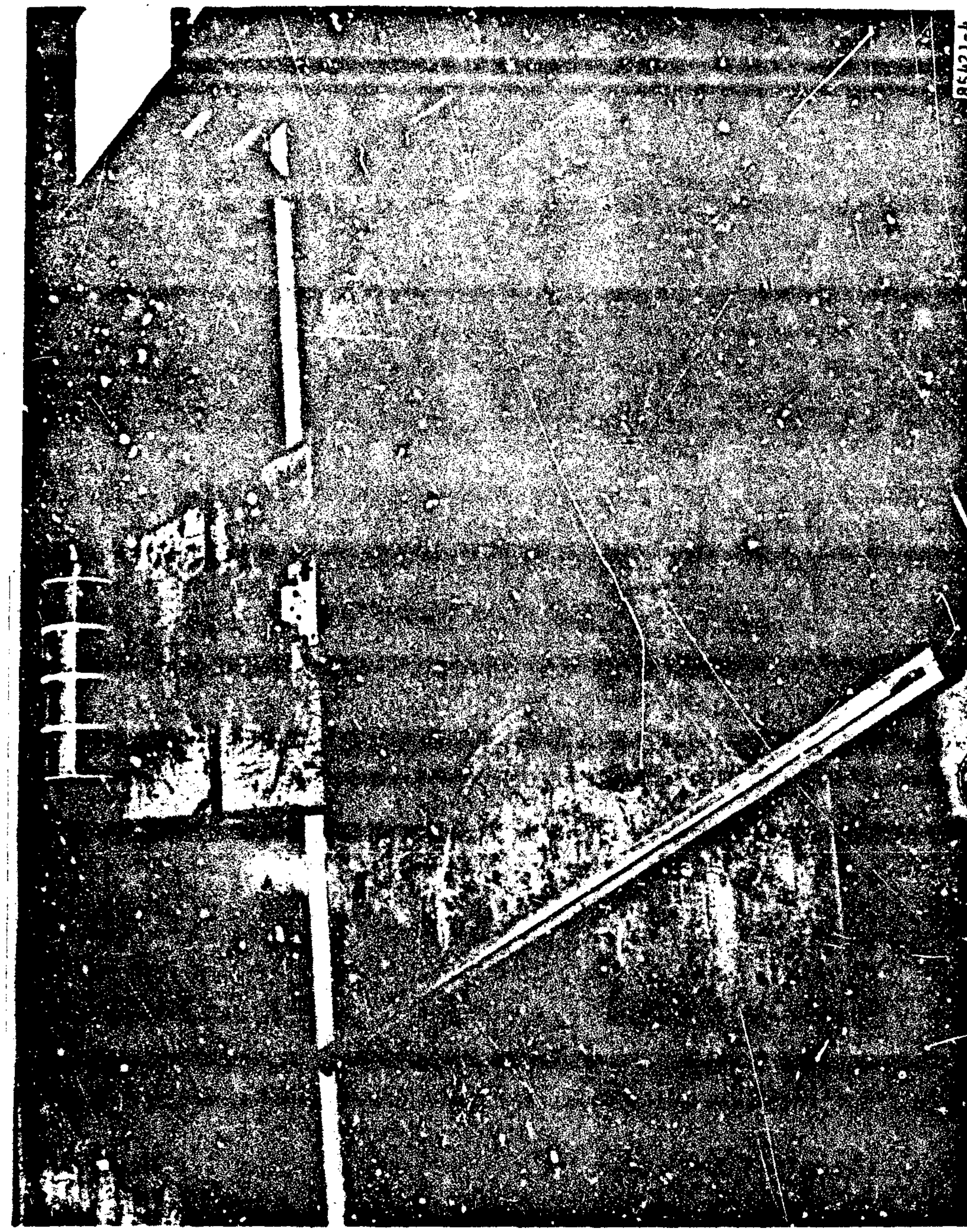

Figure 2-4. Prototype Winding Fixture

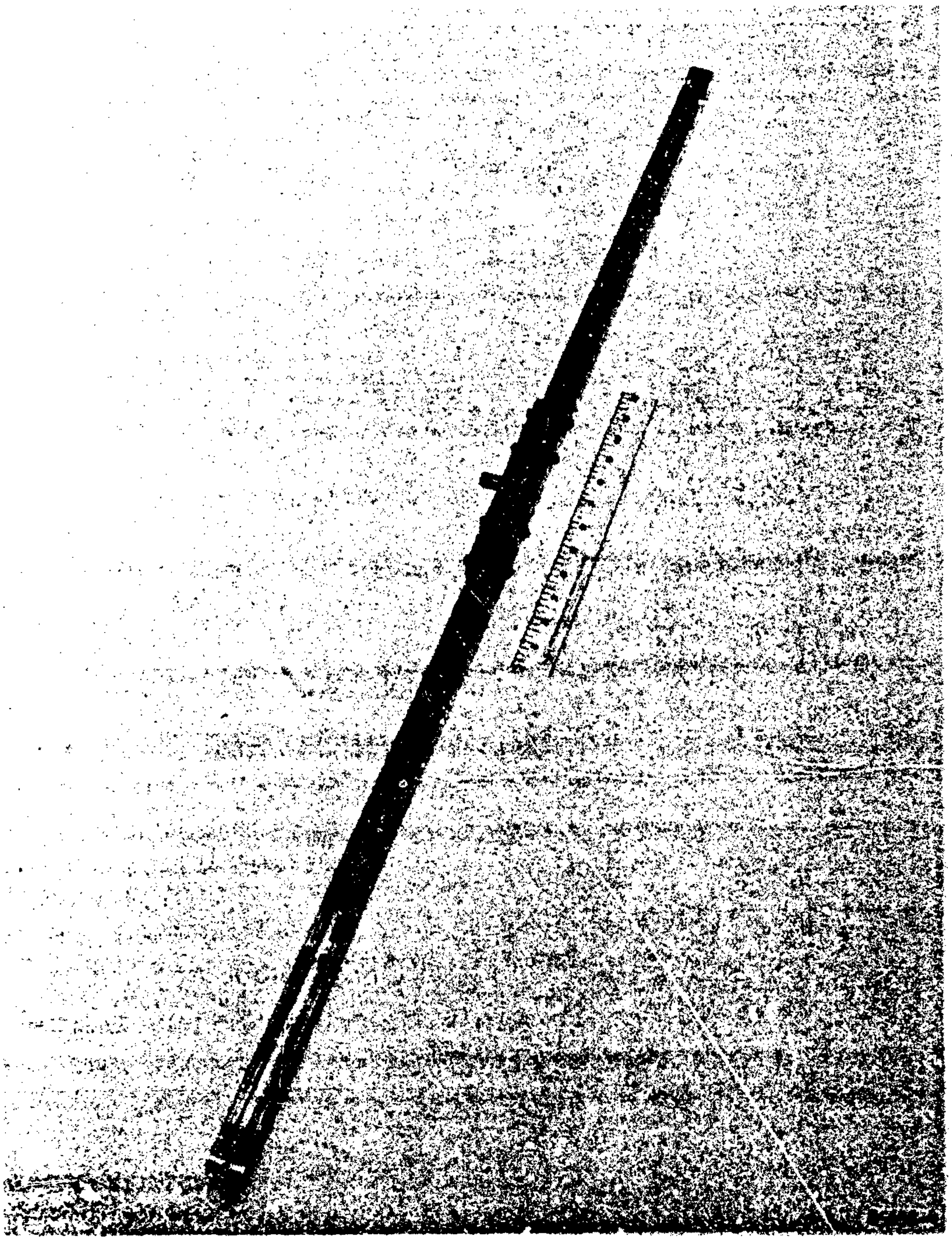

Figure 2-5. Hairpin Winding Fixture

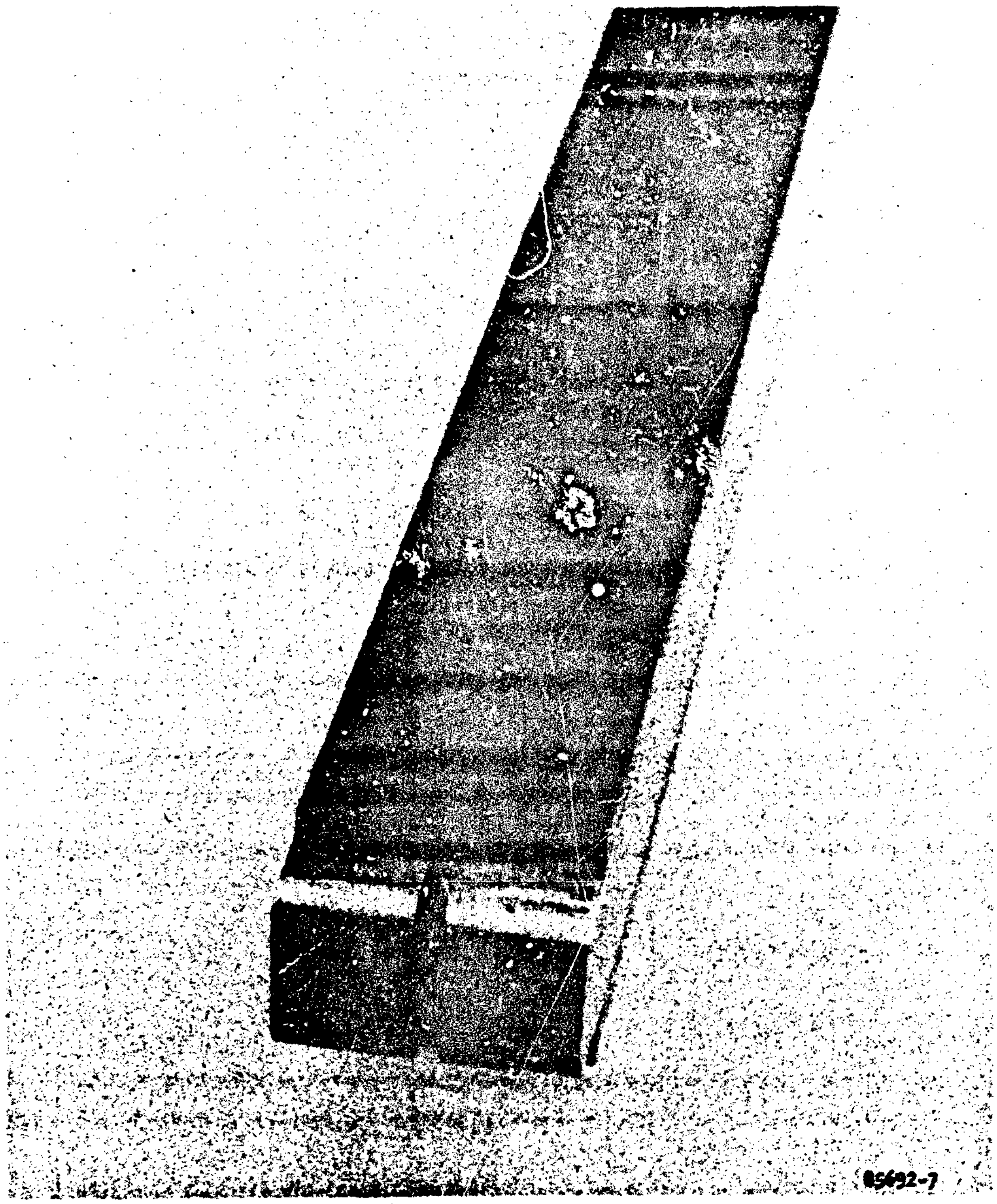

Figure 2-6. Winding Knuckle End in Fixture

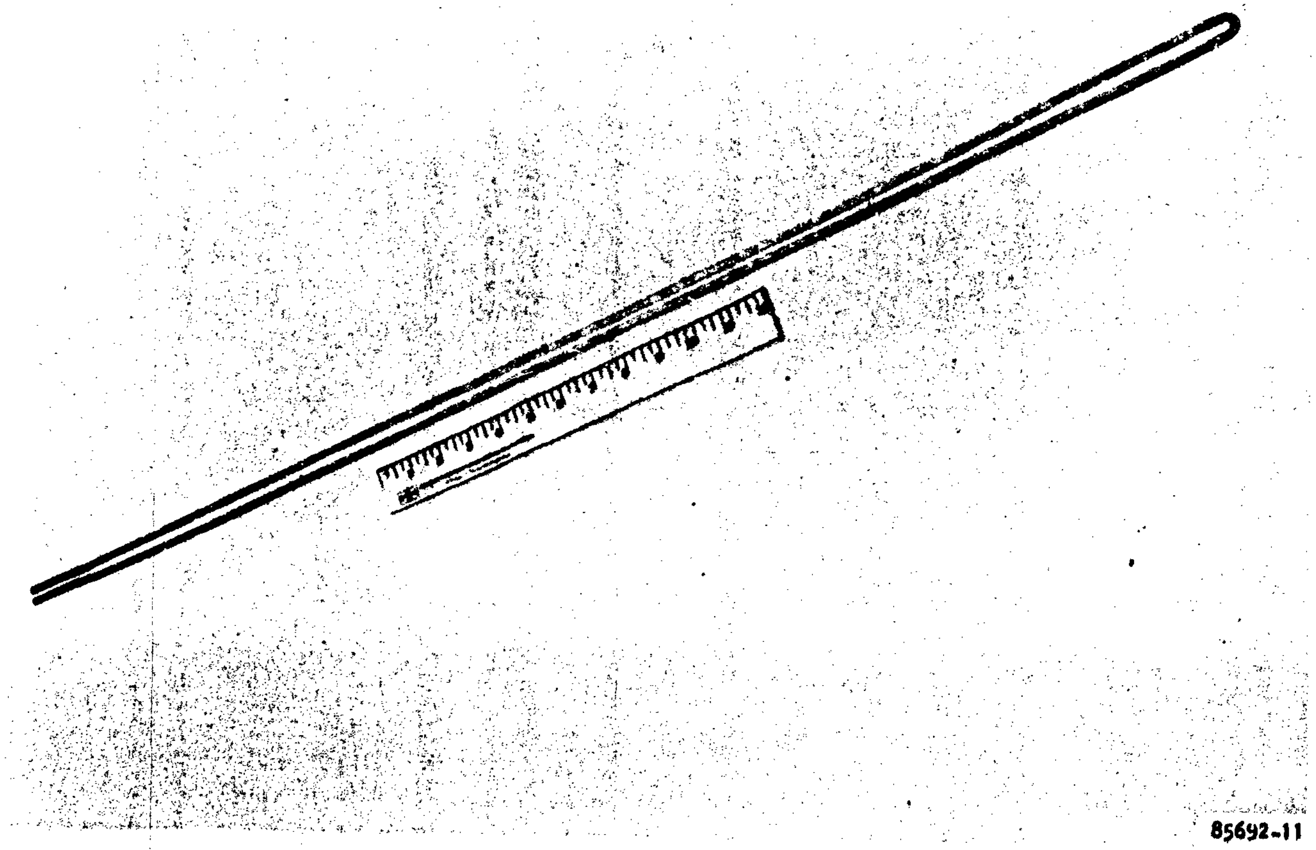

Figure 2-7. Hairpin Winding

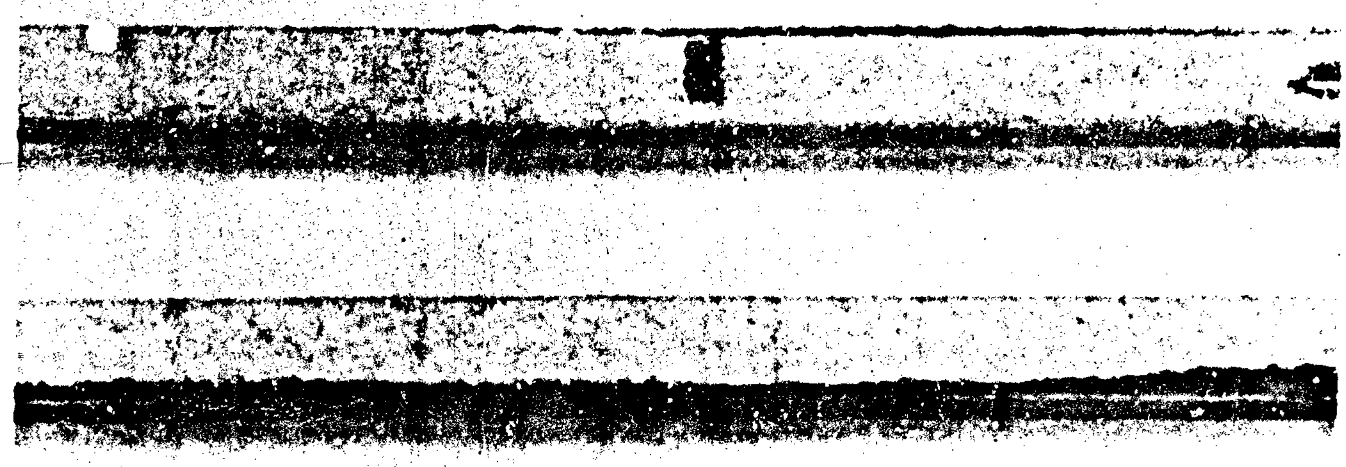

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Figure 2-8. Coolant Hole in Nomex Jacket

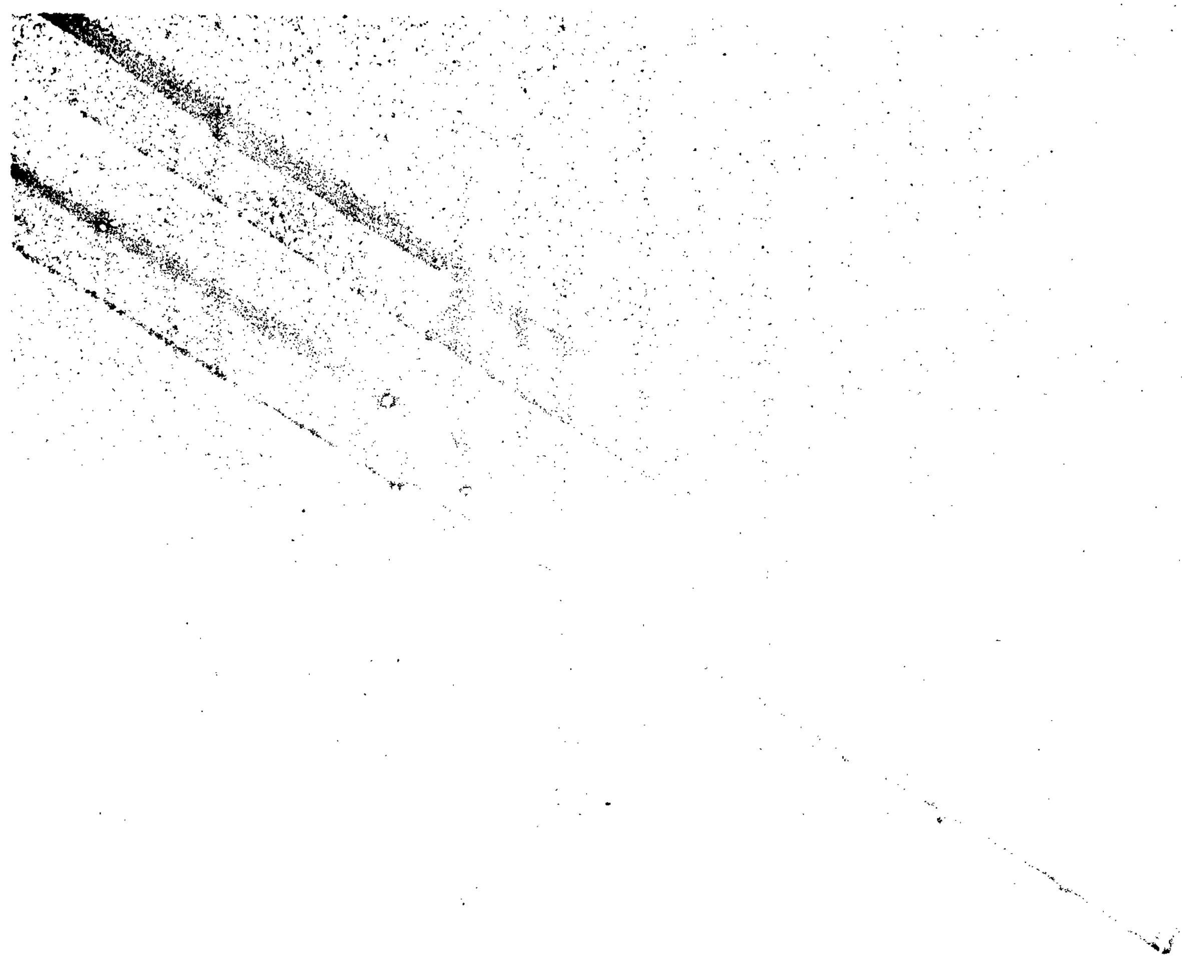

Figure 2-9. Winding Lead Extensions

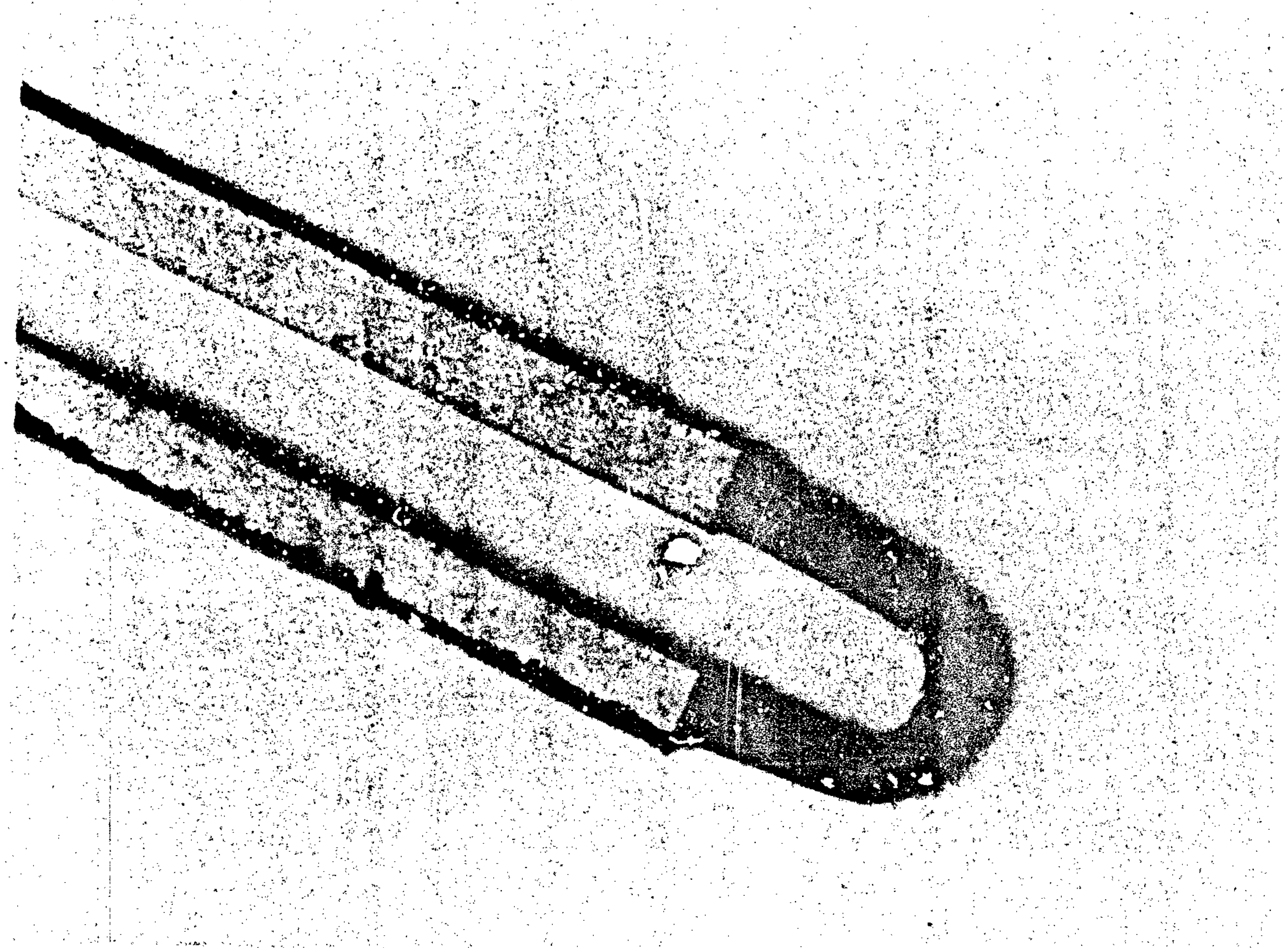

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Figure 2-10. Winding Knuckle End

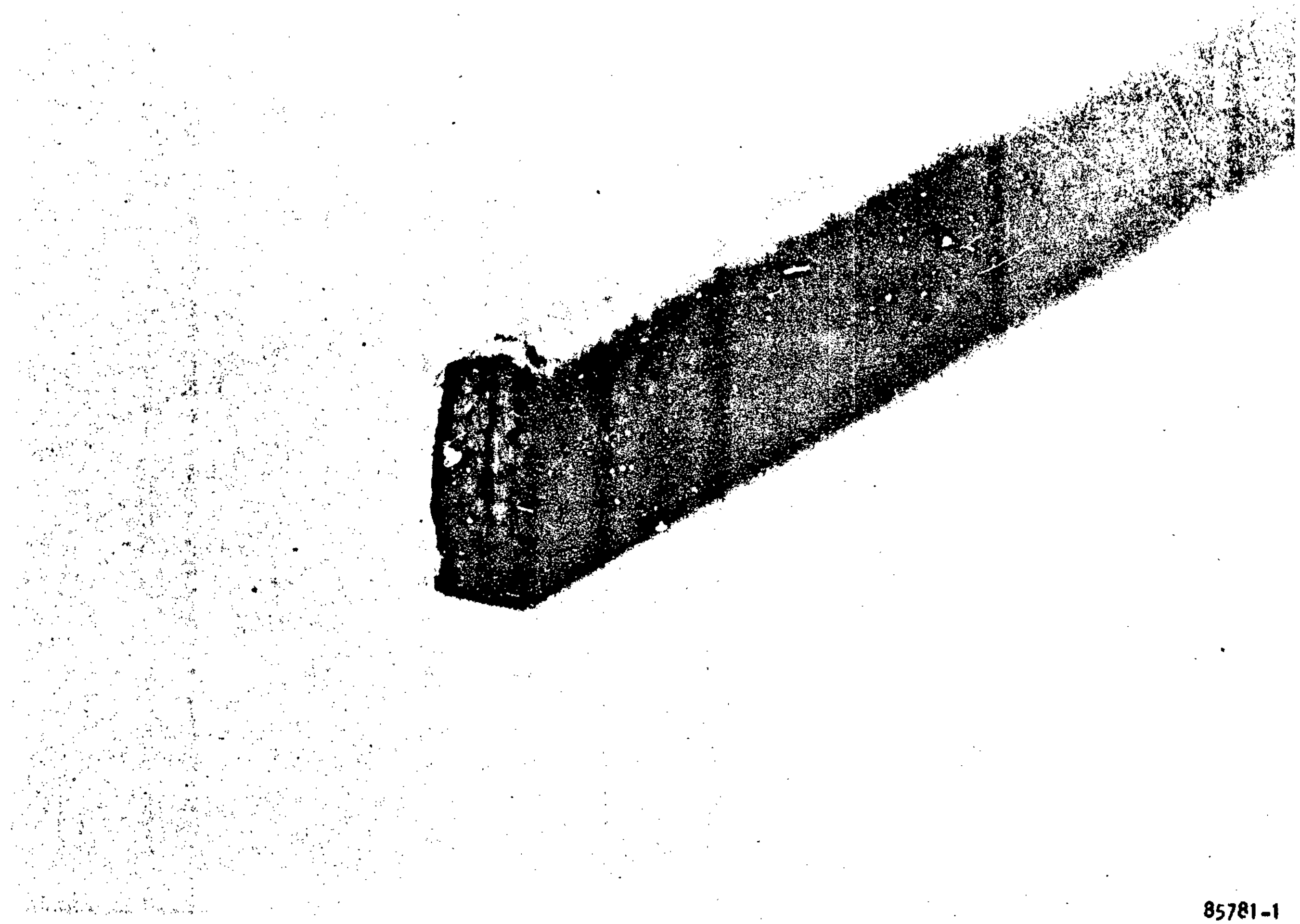

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Figure 2-11. Cross Section of Conductor

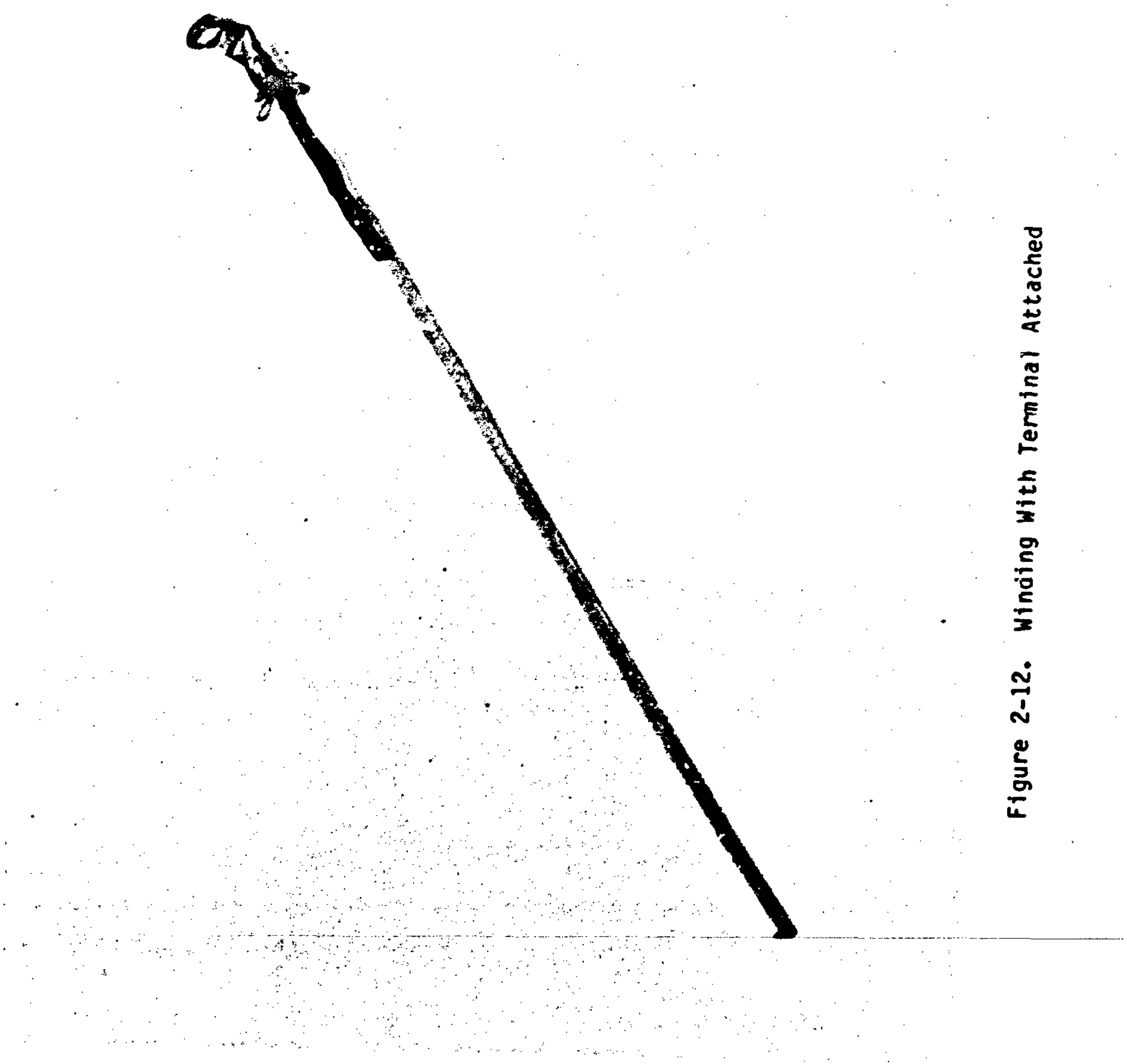

Figure 2-12. Winding With Terminal Attached

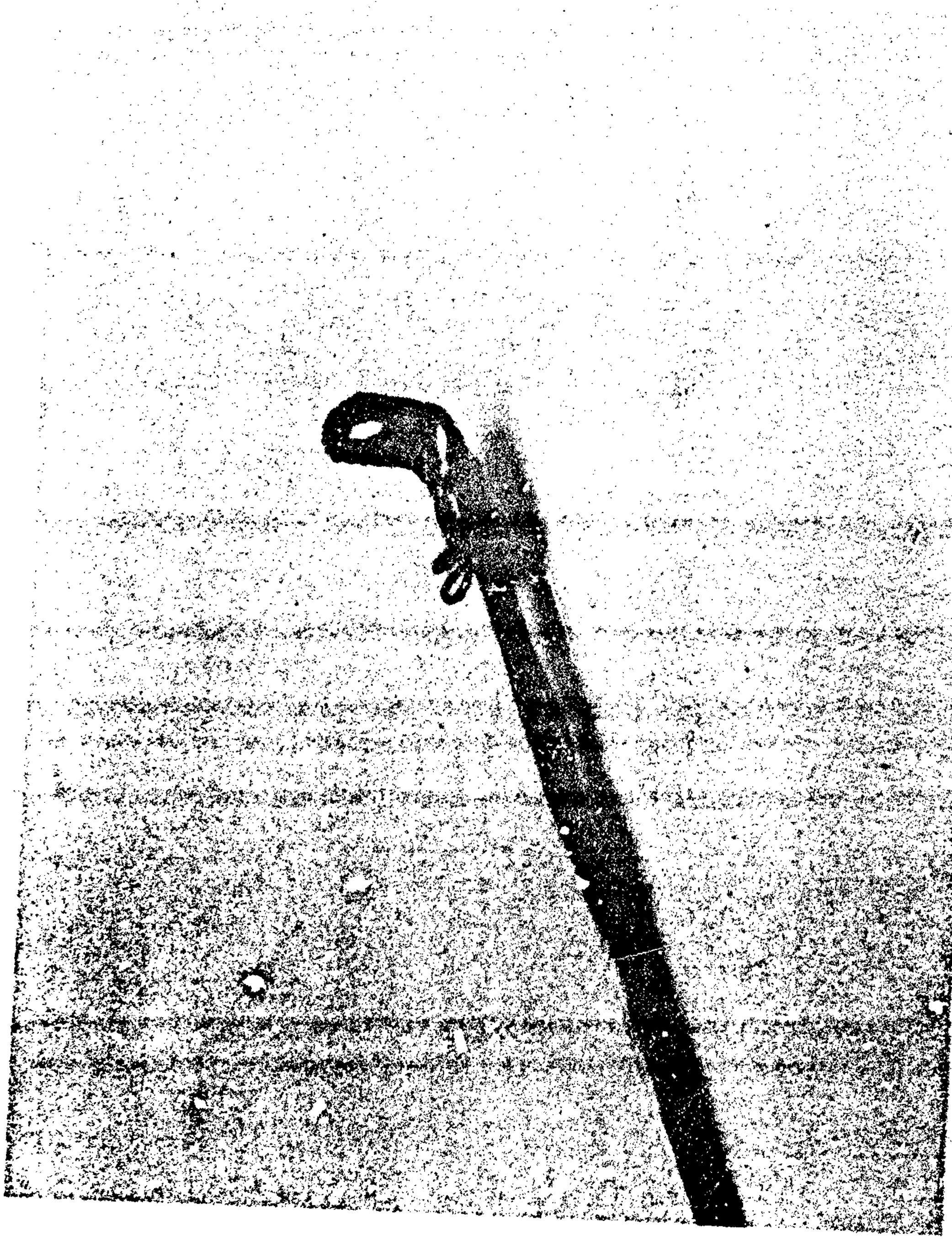

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Figure 2-13. Winding With Terminal Attached (Detail)

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Figure 2-14. Punch for Cooling Holes in Conductor Insulation

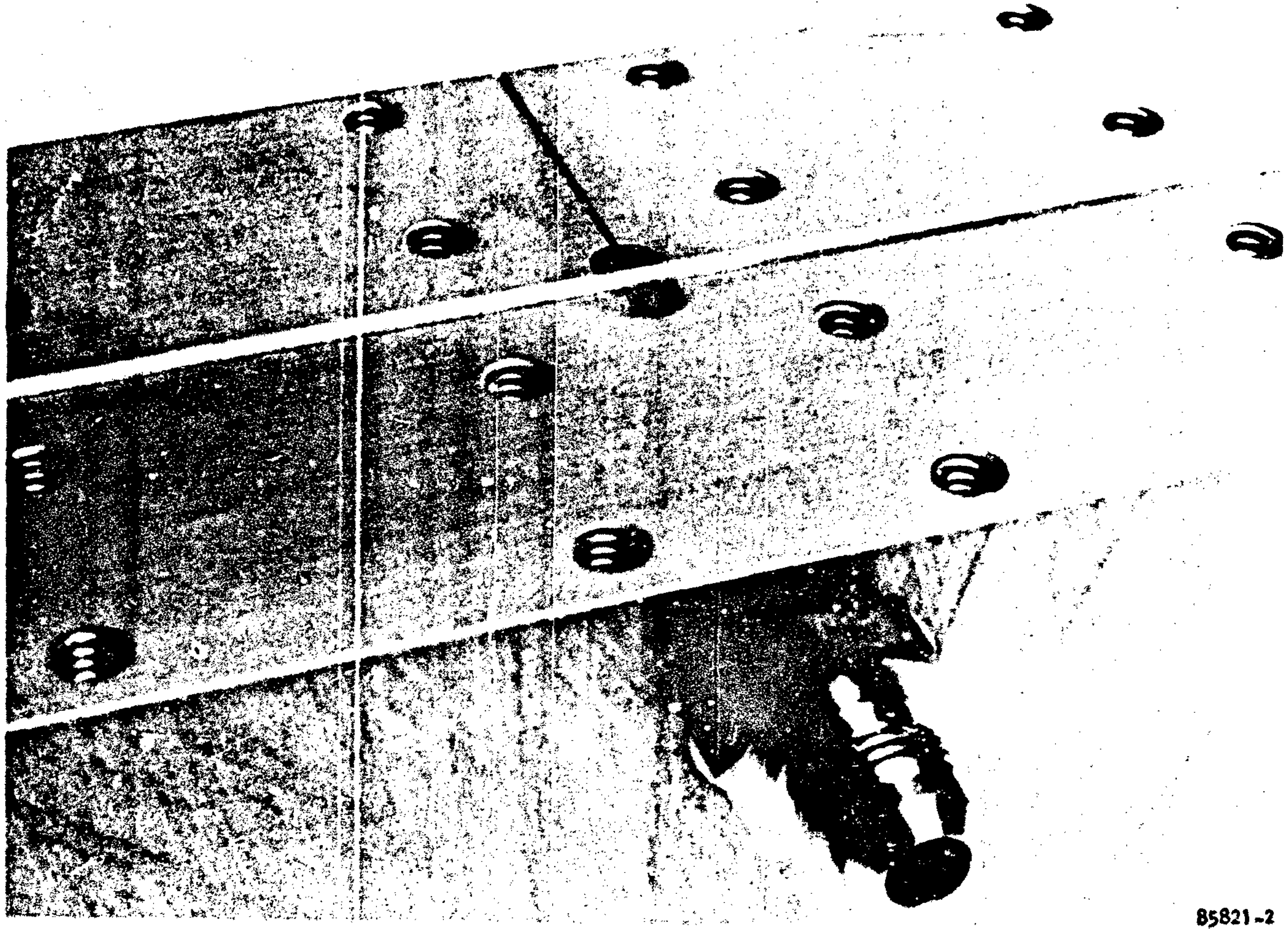
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Figure 2-15. Punched Conductor in Test Fixture

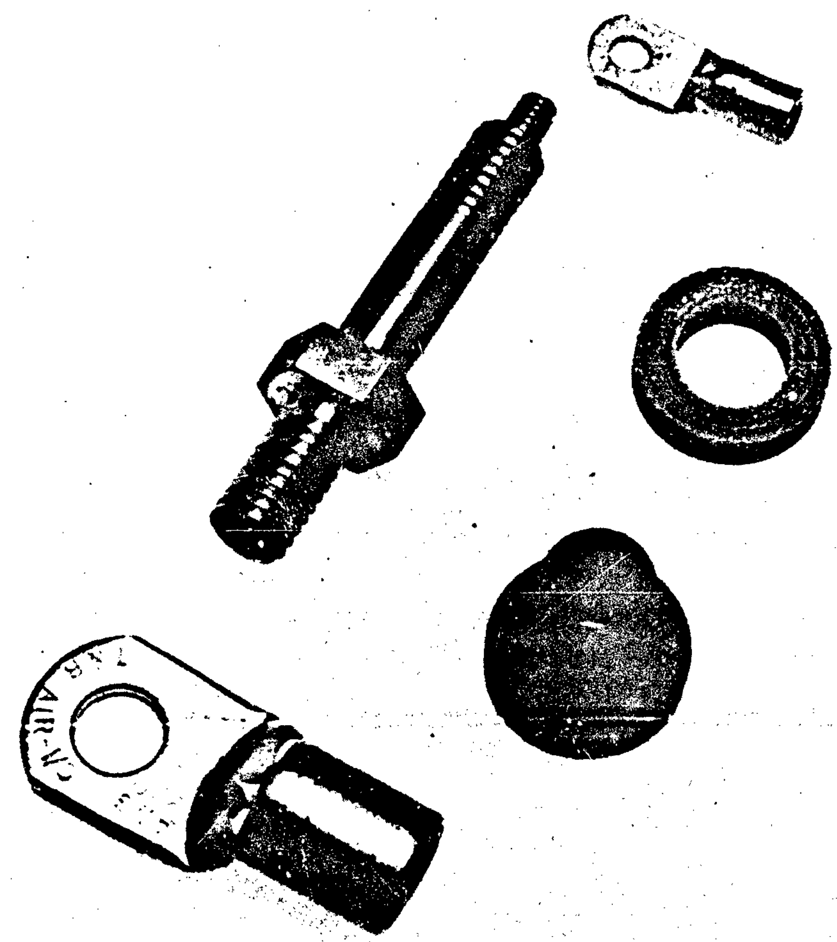

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Figure 2-16. Conductor Terminal Assembly

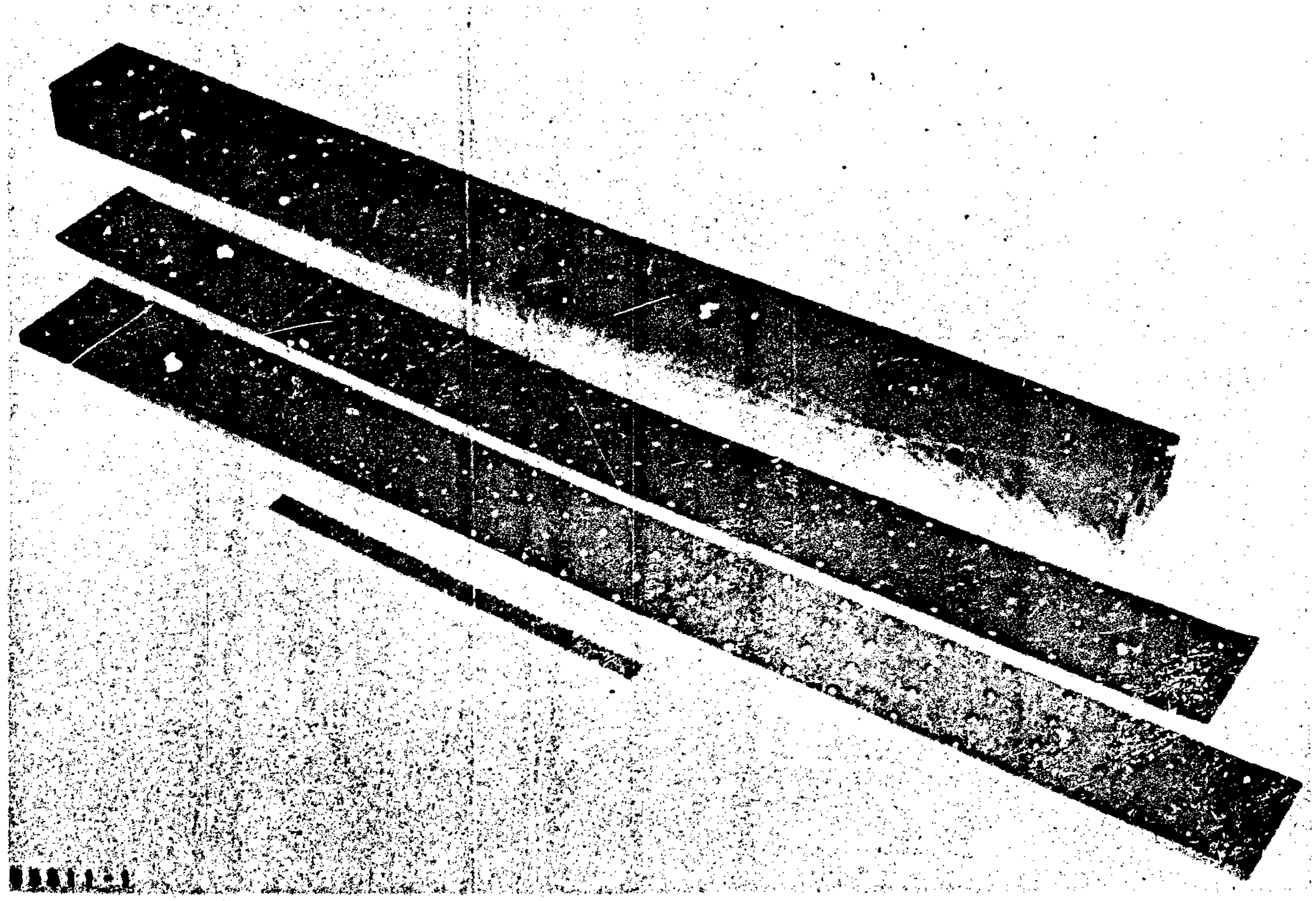

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Figure 2-17. Unassembled Hairpin Winding Test Fixture

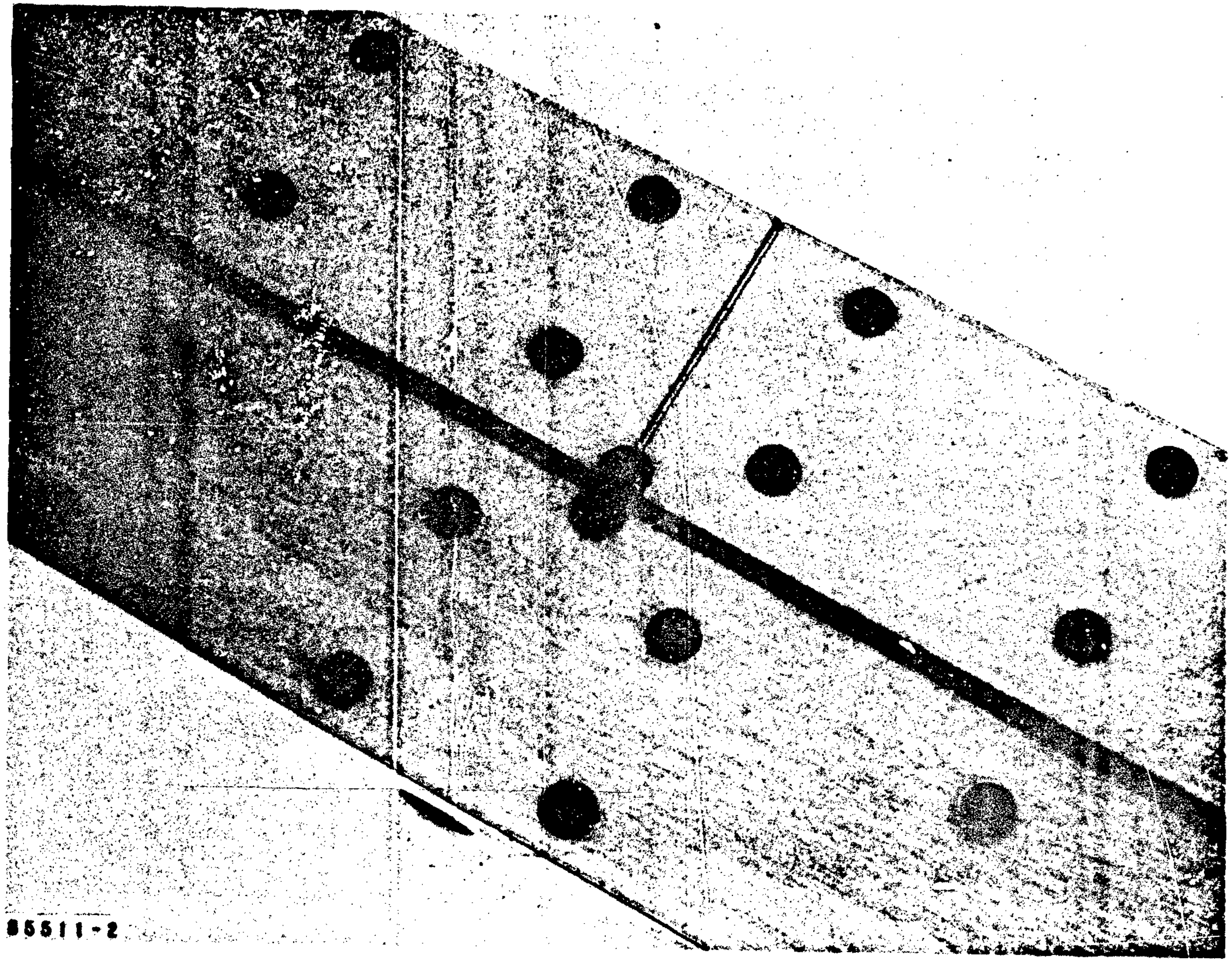

Figure 2-18. Coolant Inlet Relief of the Conductor Slot Location

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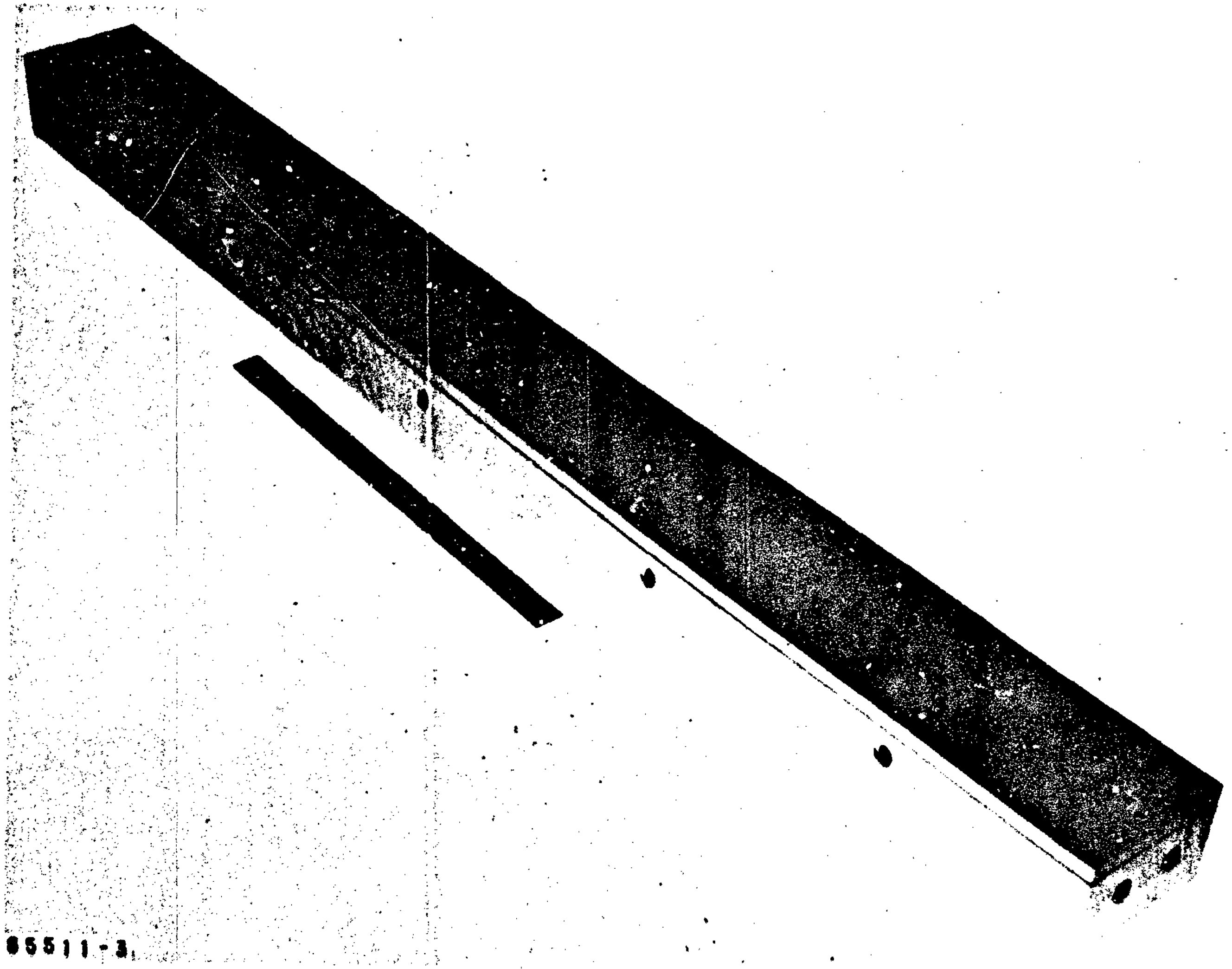

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Figure 2-19. Assembled Hairpin Winding Test Fixture

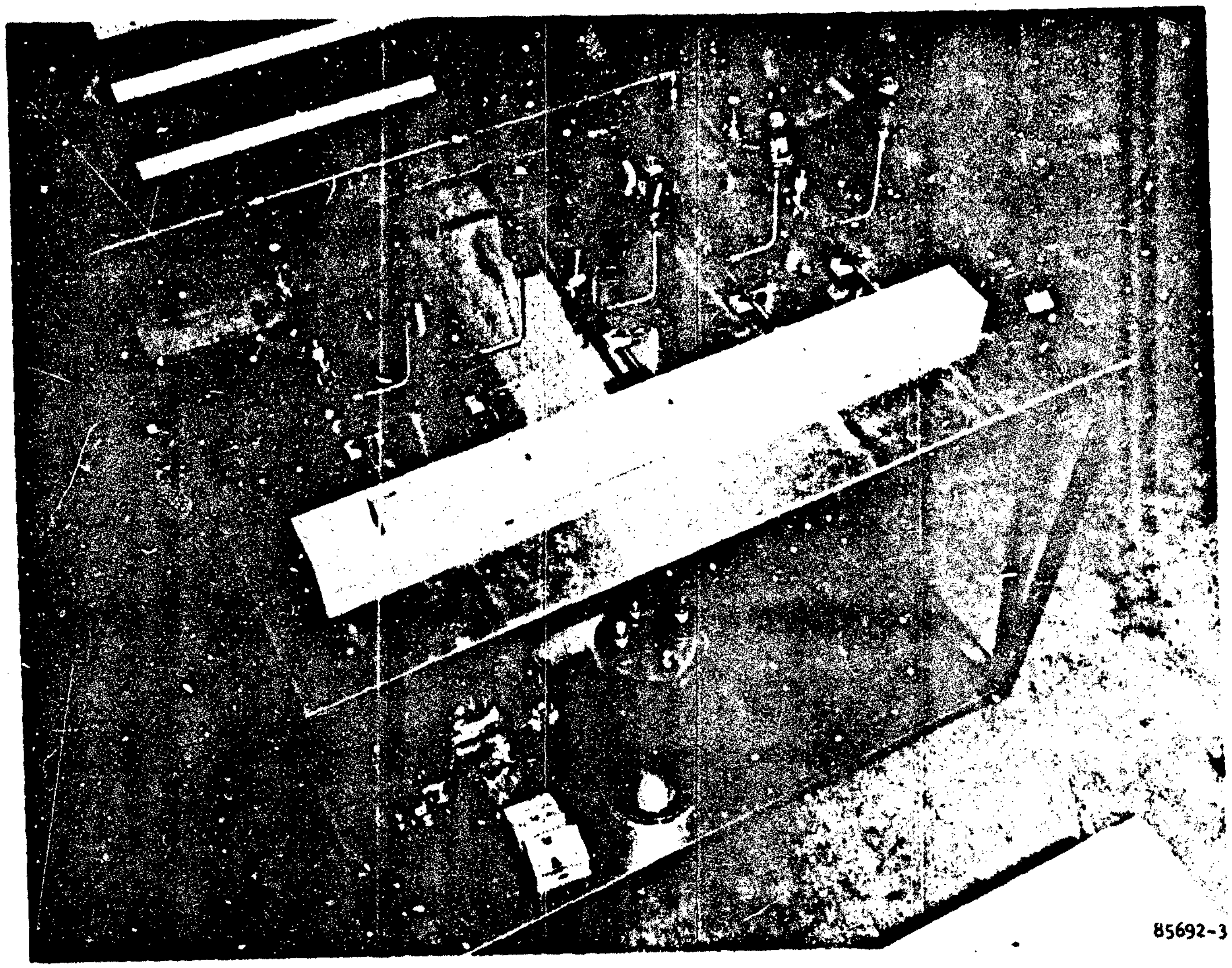

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Figure 2-20. Flow Test Setup Overview

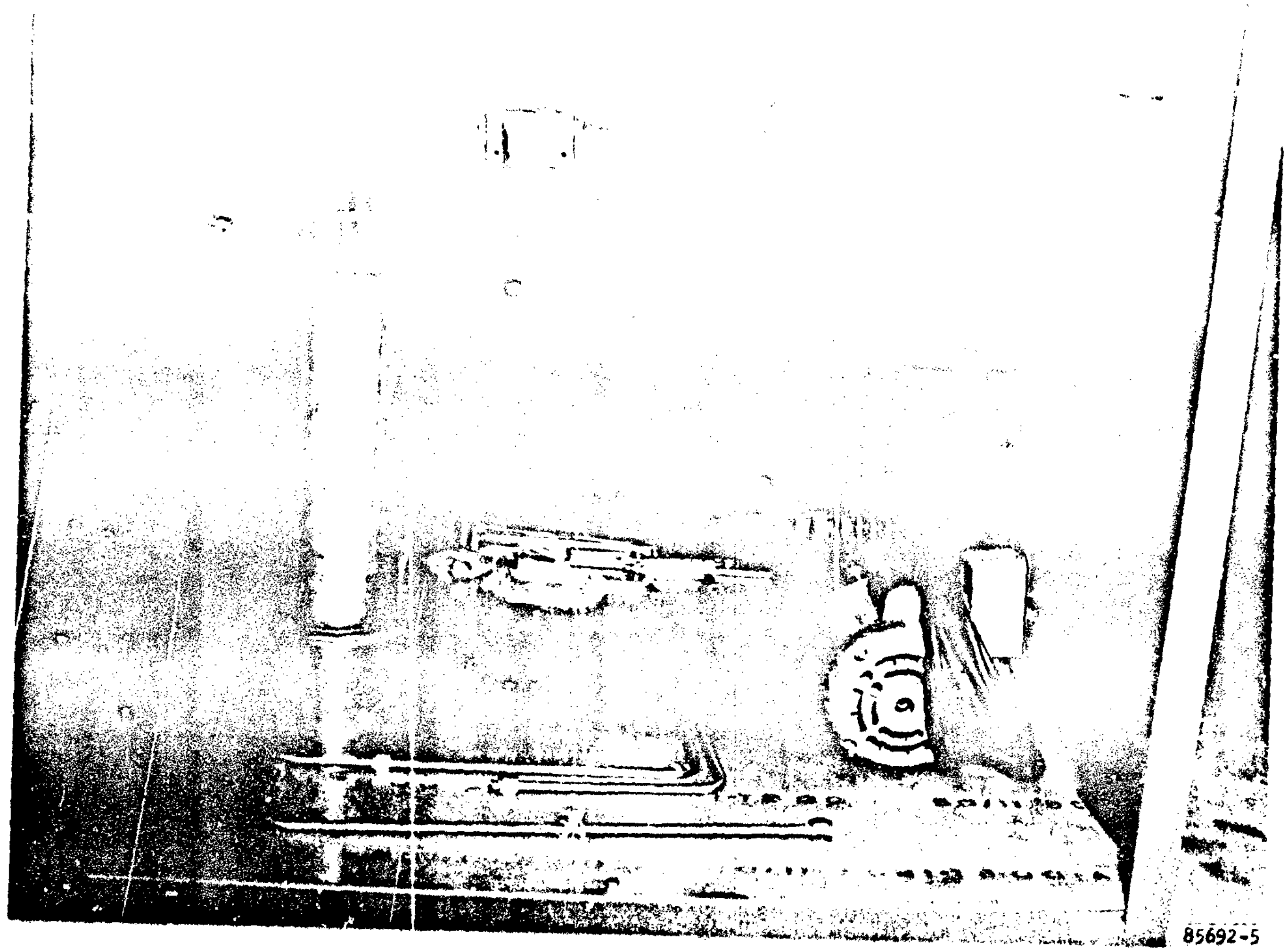

Figure 2-21. Flow Test Setup Detail

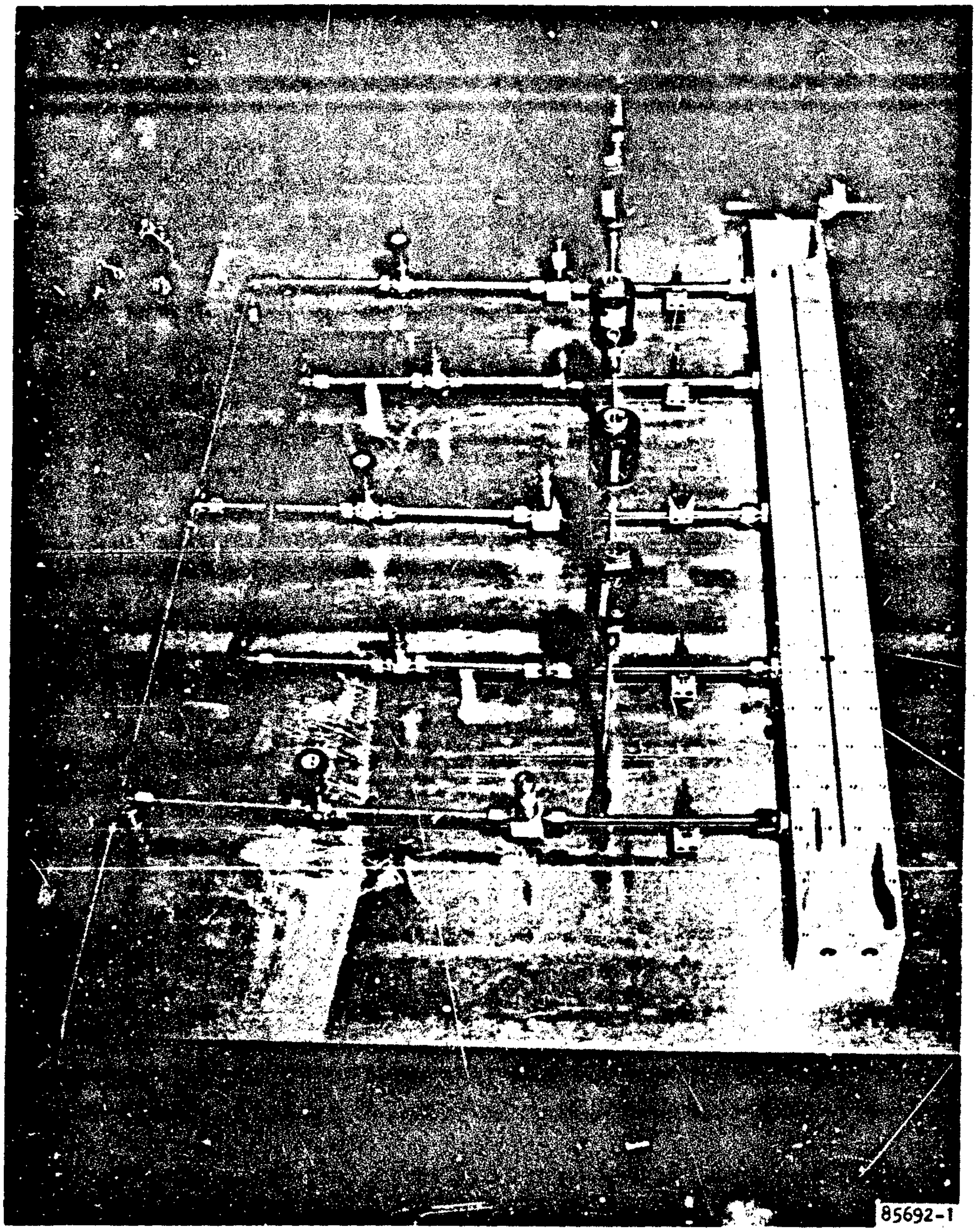

Figure 2-22. Flow Test Setup

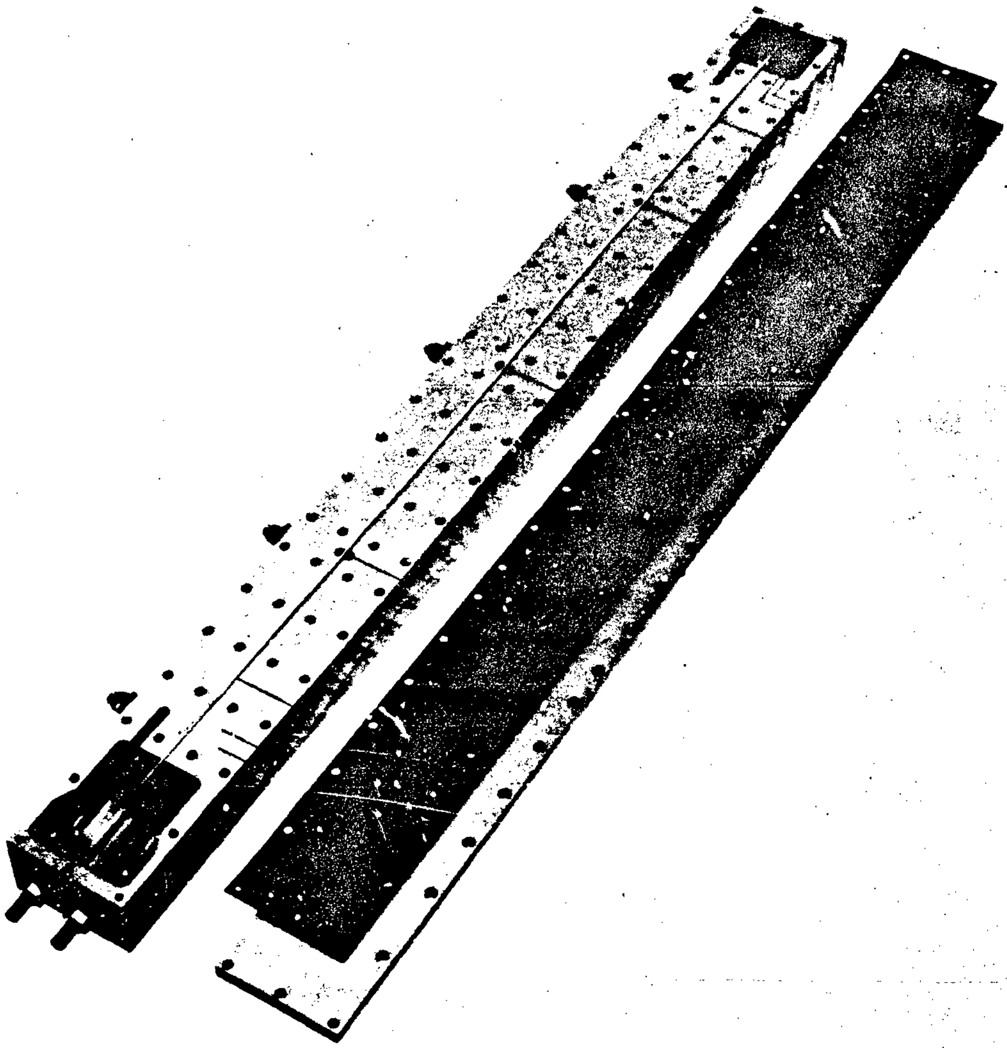

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Figure 2-23. Conductor Installed in Flow Test Fixture

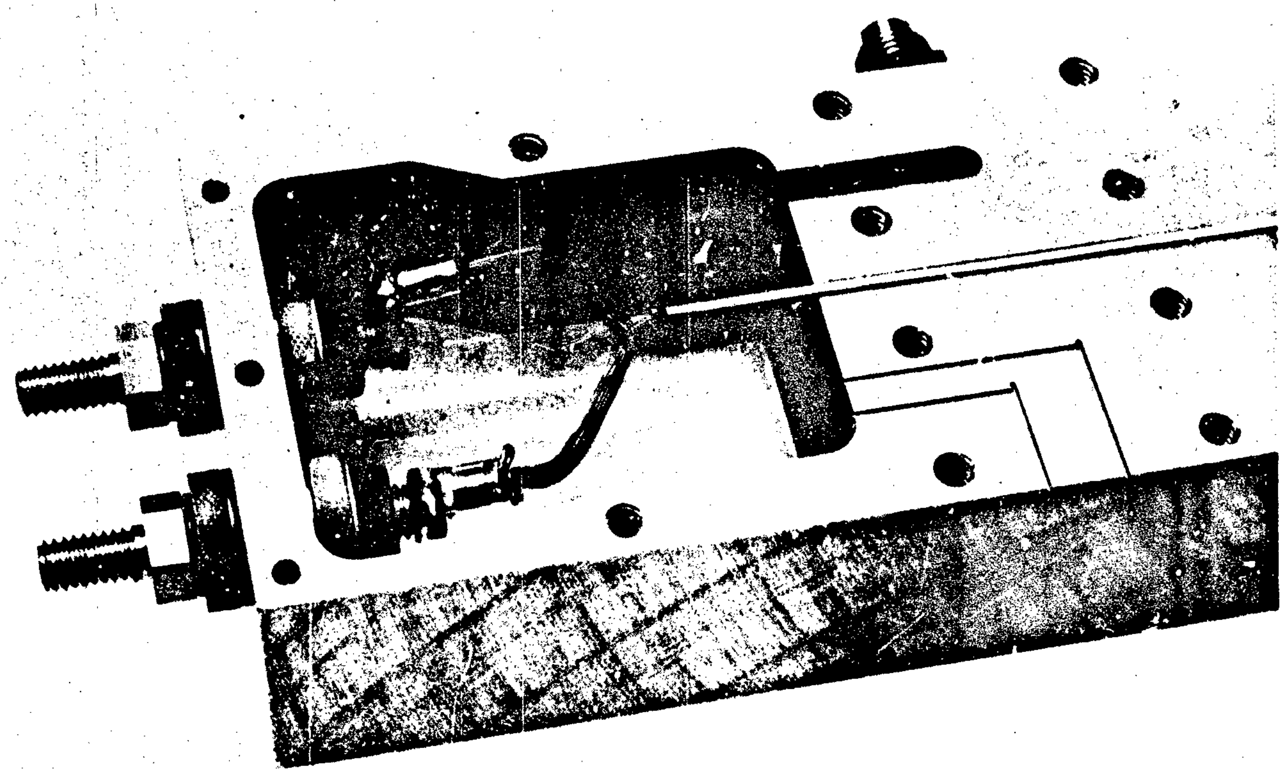

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Figure 2-24. Conductor Terminals

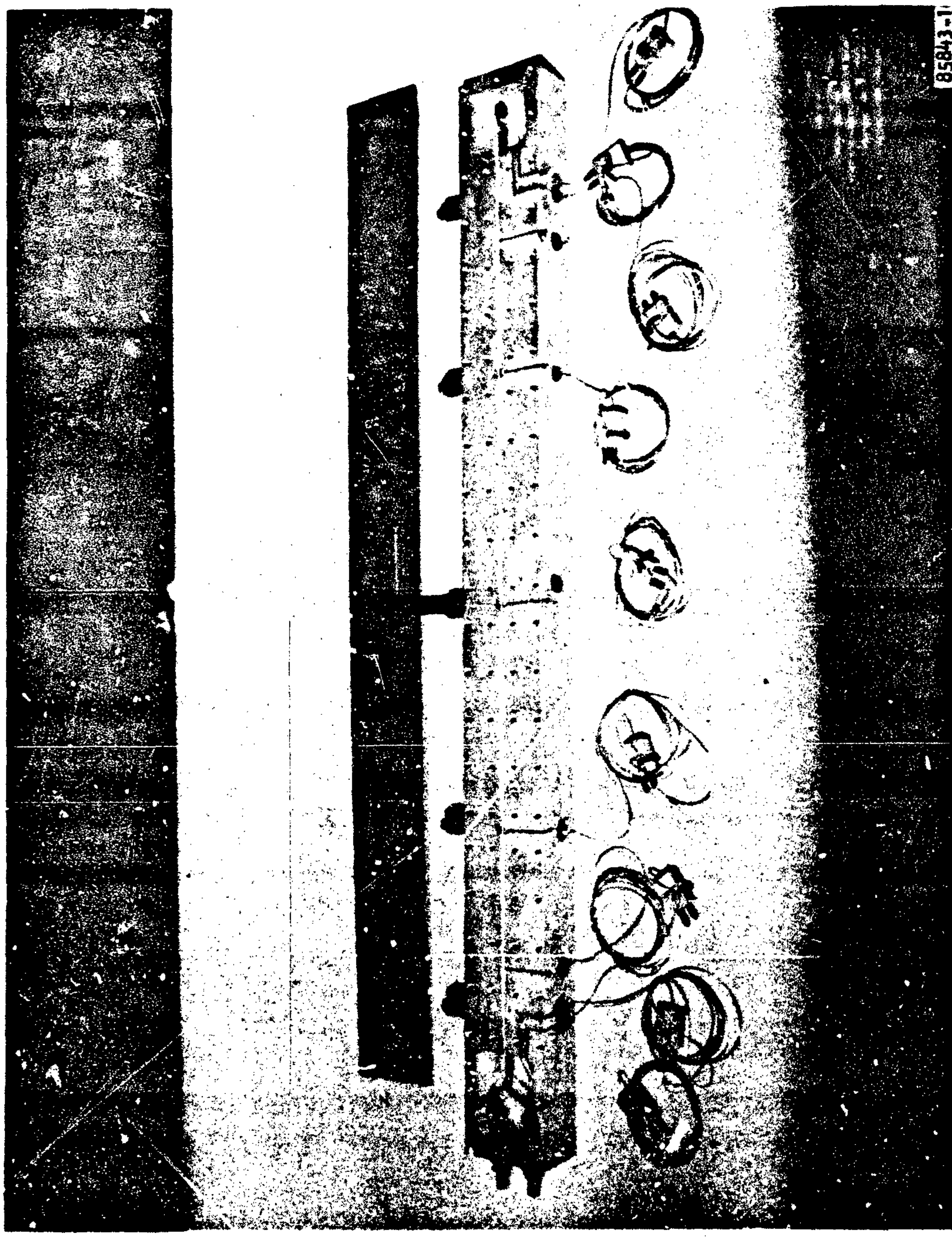

Figure 2-25. Test Fixture Showing Jacket End-Lacing and Thermocouple

EXHIBIT 2A

AIRESEARCH MEMO 19318-45609-019

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

OFFICE MEMO

IN REPLY REFER TO:
19318-45609-019

TO:	A. Druzsba	DEPT. 93-8		DATE:	Oct. 15, 1981
FROM:	C. Gibson	DEPT. 93-18	EXT. 3505	COPIES TO:	P. Fizer F. McCarty K. Ramezani
SUBJECT:	Assembly of the Advanced 5MW Permanent Magnet Generator Conductors into Insulating Jackets.				

Introduction

The materials used to bond the conductors together for assembly were the following:

Material	Source
Vitel VPE-5571	Goodyear Tire and Rubber Co., Chemical Division
Methylene Chloride	Commercial
Trichloroethane	Commercial
Perchloroethylene	Commercial

Typical Adhesive Formulation	
Vitel VPE-5571	450 grams
Methylene Chloride	3.00 liters
Trichloroethane	.75 liters
Perchloroethylene	.25 liters
Total	4.00 liters

Vitel VPE-5571 is a polyester resin that exhibits high specific adhesion to various substrates, the most important being polyethylene terephthalate film (e.g. Mylar). Its excellent chemical and thermal stability, flexibility, and cohesive strength make it a good candidate for bonding polyester films to copper foils and wires for the electronics industry. In addition, it has high solubility in chlorinated organic solvents and will also melt flow at temperatures below 450° F. For these reasons, it was chosen as the bonding agent for assembling the conductors into the Nomex paper insulating jackets.

Procedure (See Figure 1)

Assembly (performed by P. Fizer and K. Ramezani).

The conductors were aligned, coated with the Vitel-5571 bonding solution and allowed to air dry at room temperature for approximately 10 to 20 minutes in band widths of four strands each. The banded conductors were then placed nine layers high into an insulator jacket that was coated with the Vitel adhesive on its internal walls. A grooved metal fixture was used to assist in the holding of the insulator jacket during the stacking of the conductor bands. This procedure was repeated to produce two Nomex paper jacketed, 4 x 9 conductors each 16 inches long.

Vitel VPE-5571 Removal

The conductor samples each had a small (approx 0.1 inch in diameter) oil flow passage cut through the insulating jacket at their mid sections. They were then placed into the grooved metal fixture in a slot sample configuration (as defined by P. Fizer) with both ends open.

FORM 794-1 (11-79)

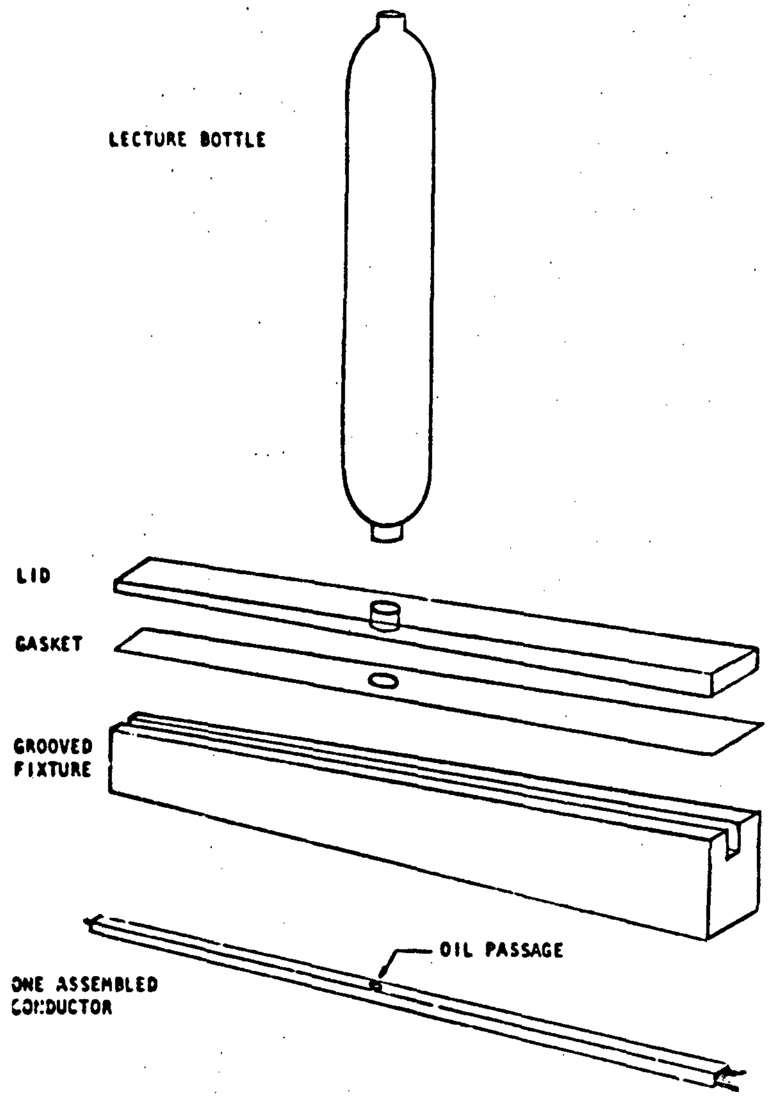

Figure 1. Fixture Components for Conductor Assembly

Ref: 19318-45609-019

October 15, 1981

The metal fixture was then fitted with a rubber gasketed lid that sealed the open groove to form an enclosed channel around the conductors. A pressurized nitrogen line was fitted at a threaded opening in the lid over the conductors' oil passages. This assembly was then heated to 450° F in an air circulating oven and a low flow of nitrogen was passed through the conductors.

After the dripping of the Vitel adhesive from the open ends appeared to stop, the assembly was removed from the oven and prepared for solvent extraction. A 250 ml, metal lecture bottle reservoir was fitted to the assembly in place of the nitrogen line. Approximately 1 liter of fresh methylene chloride was passed through the assembly by gravity addition. This was followed by an approximately 1 liter methylene chloride power flush by applying a low nitrogen pressure to the top of the lecture bottle. The cleaned conductors were then dried by allowing a low flow of nitrogen to pass through the system at room temperature for 10 minutes.

The conductors were then removed from the assembly, sectioned, and visually inspected at 30 x for cleanliness. No adhesive was noted.

<u>Conclusions</u>

The procedure used in this first, cursory study was the best that could be conceived without extensive testing. Additional study is needed to minimize pressure, temperatures and solvent volumes before the development unit is assembled.

Chris Gibson

Chris Gibson
Materials Engineering

Approved D.W. McGrath
D. W. McGrath
Materials Engineering

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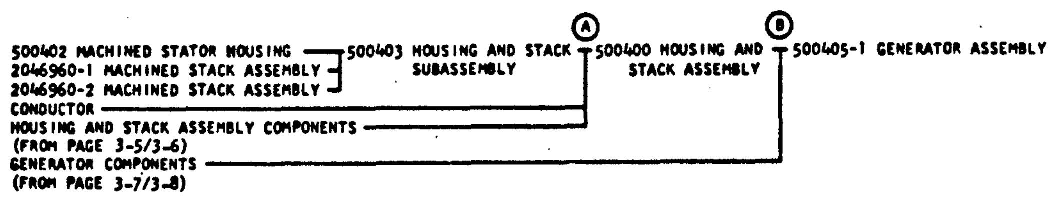
3. DETAIL DESIGN REVIEW

During Phase II the final detail designs were completed. These designs are fully compatible with the rotor scheduled for delivery early in 1982. These designs were incorporated into the fabrication drawings which form the basis for the rotor fabrication plan.

3.1 FABRICATION PLAN

AiResearch manufacturing engineering participated in the detail design process; each detail was reviewed for producibility and was approved by the cognizant manufacturing engineer before it was released to production. In preparation of the fabrication plan, the manufacturing operations were determined by the manufacturing engineer. These operations are presented in Figure 3-1. This figure shows the sequence of operations; the time span required is reflected in Paragraph 3.2, Long Lead Item Descriptions.

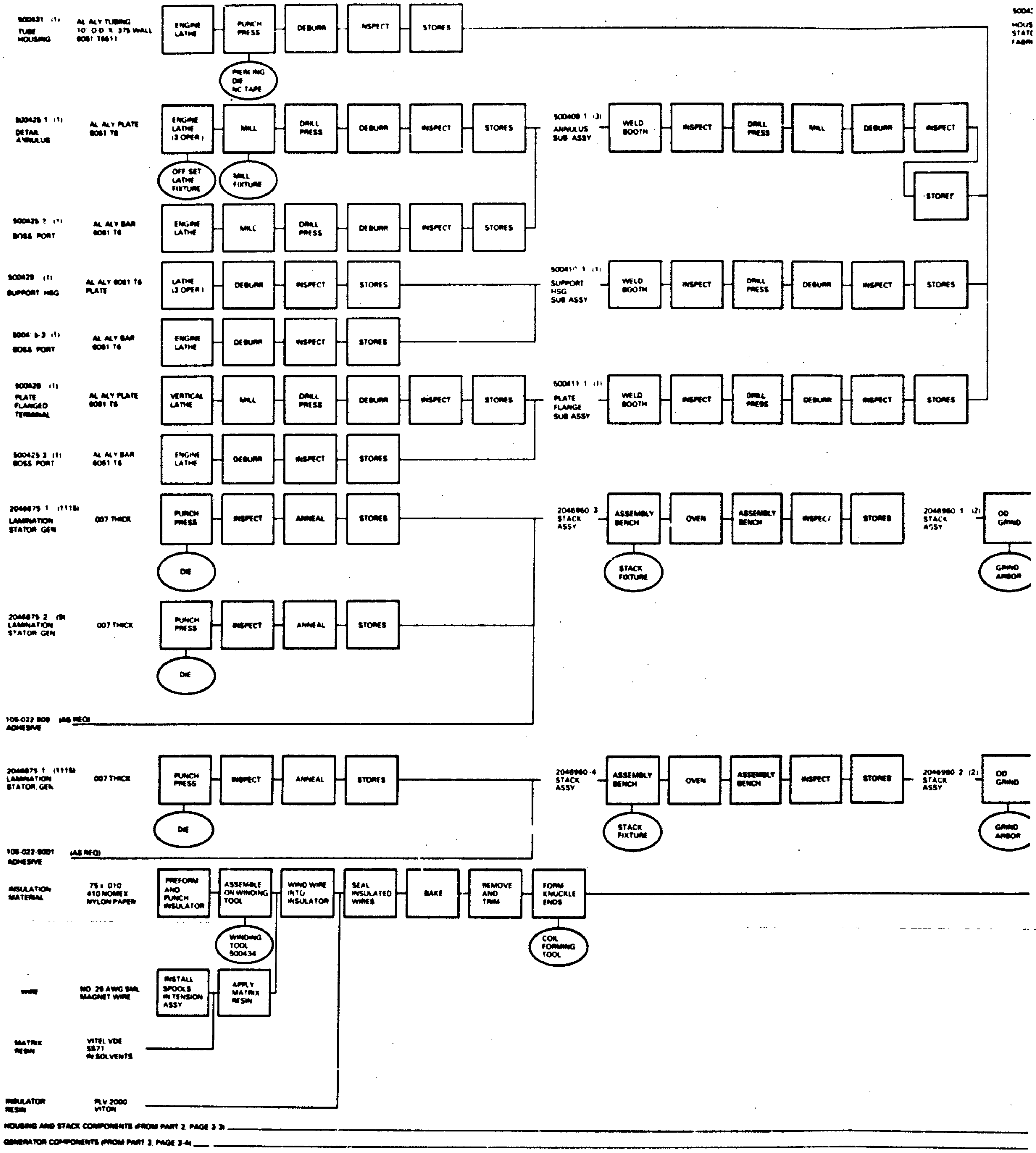
The figure is presented in three parts; parts 2 and 3 are keyed to the assembly sequence by the letters A and B as indicated below:



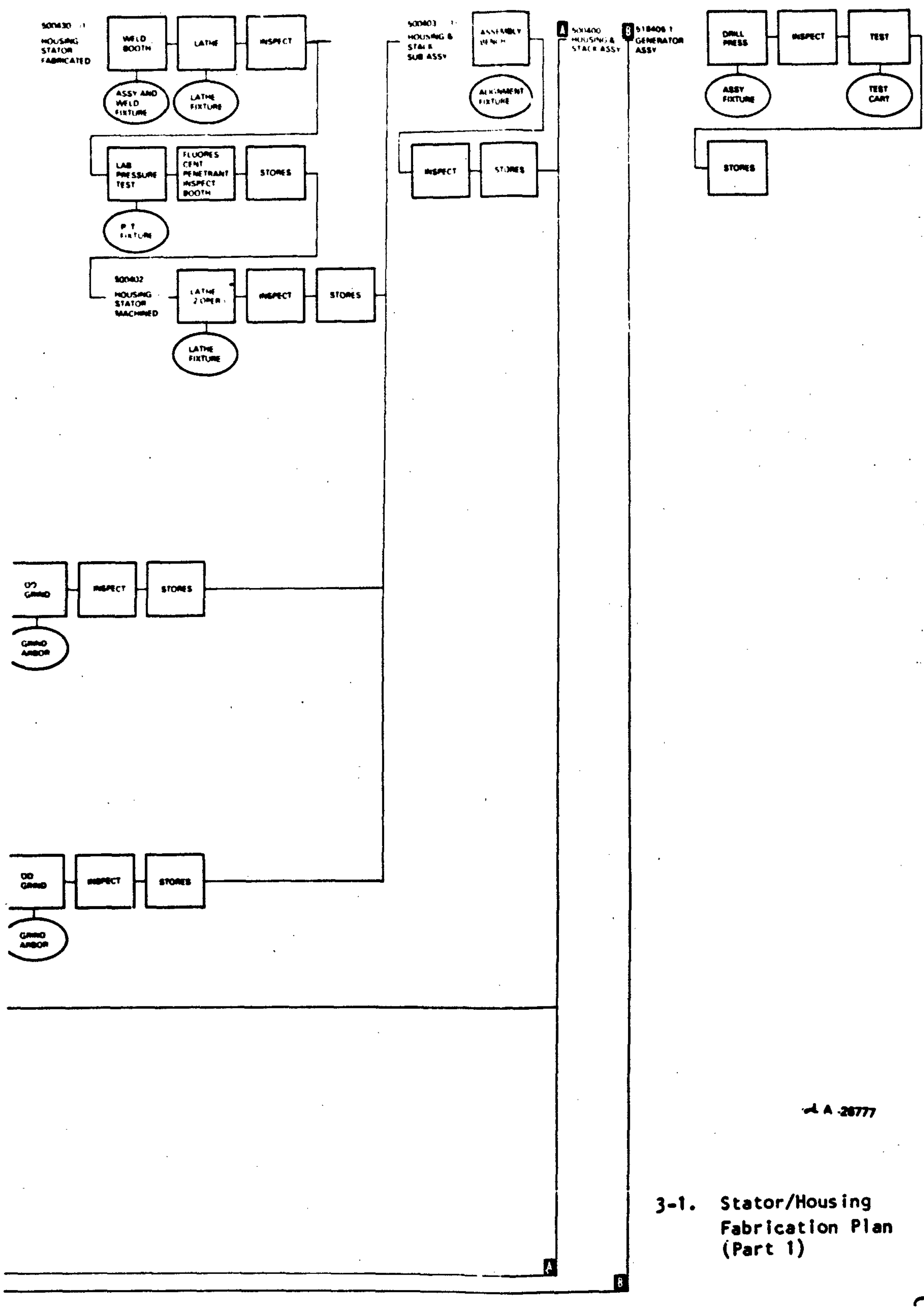
Drawings used in determining the manufacturing operations are included in numerical order at the end of this section.

3.2 LONG LEAD ITEM DESCRIPTIONS

Long lead is readily determined from the fabrication schedule presented in Figure 3-2. As shown in the figure, overall fabrication and assembly of the complete generator is 13 months.

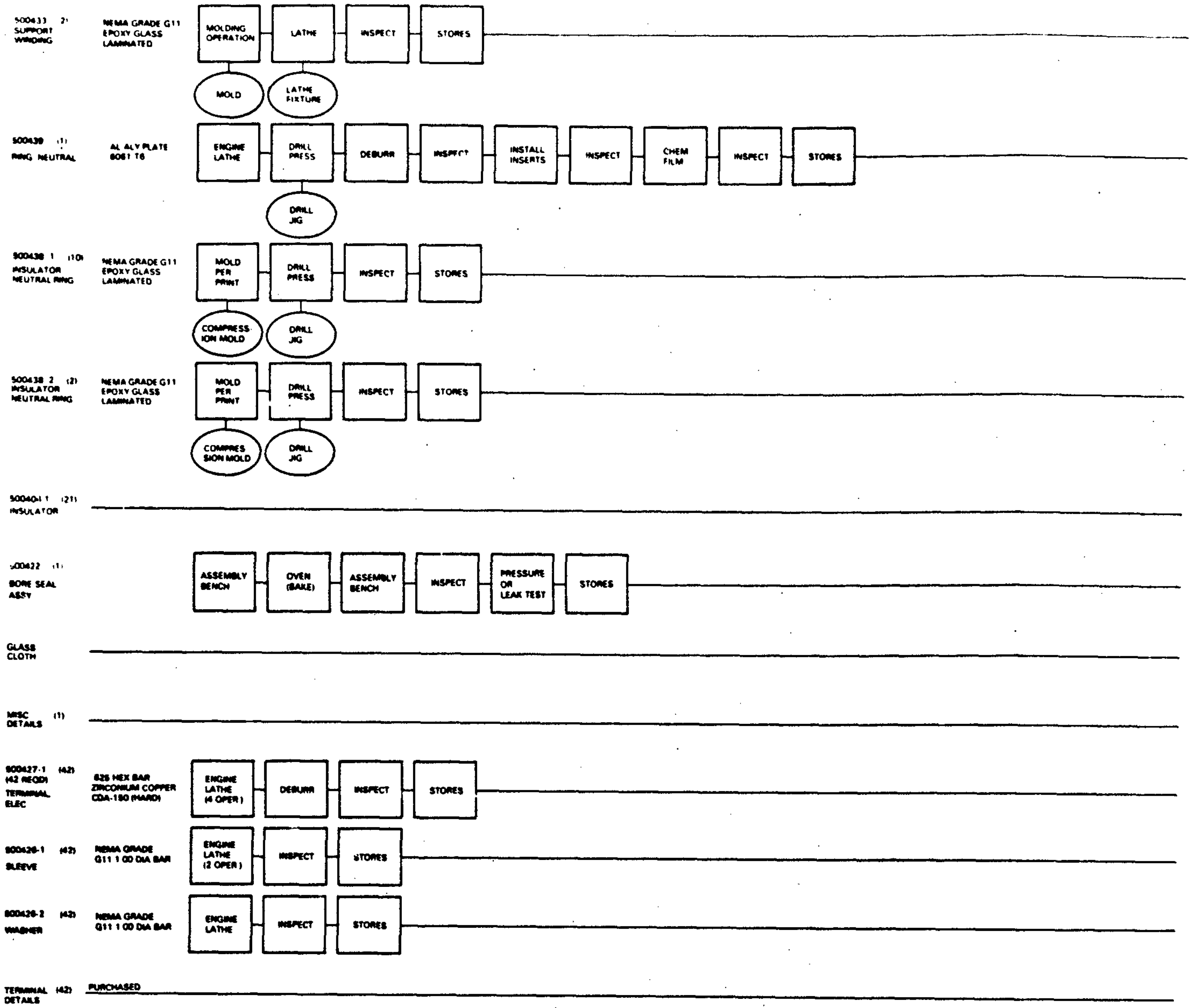


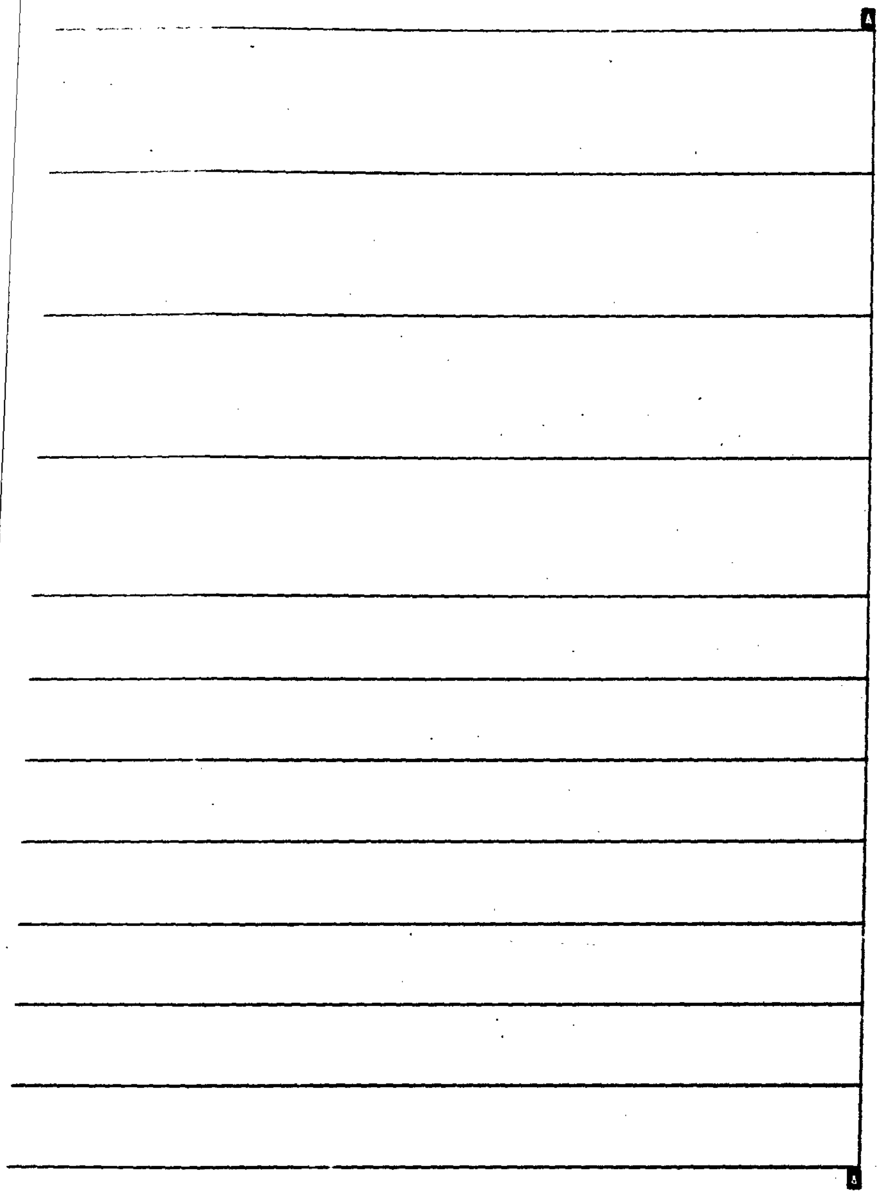
TUBE HOUSING
AL ALY TUBING
ENGINE LATHE
PUNCH PRESS
DEBURR
INSPECT
STORES
PIERCING DIE NC TAPE
DETAIL ANNULUS
AL ALY PLATE 6061 T6
ENGINE LATHE (3 OPER)
MILL
DRILL PRESS
OFF SET LATHE FIXTURE
MILL FIXTURE
ANNULUS SUB ASSY
WELD BOOTH
BOSS PORT
AL ALY BAR 6061 T6
SUPPORT HSG
LATHE (3 OPER)
SUPPORT HSG SUB ASSY
PLATE FLANGED TERMINAL
VERTICAL LATHE
PLATE FLANGE SUB ASSY
LAMINATION STATOR GEN
007 THICK
ANNEAL
DIE
STACK ASSY
ASSEMBLY BENCH
OVEN
STACK FIXTURE
OD GRIND
GRIND ARBOR
ADHESIVE
(AS REQ)
INSULATION MATERIAL
410 NOMEX NYLON PAPER
PREFORM AND PUNCH INSULATOR
ASSEMBLE ON WINDING TOOL
WIND WIRE INTO INSULATOR
SEAL INSULATED WIRES
BAKE
REMOVE AND TRIM
FORM KNUCKLE ENDS
WINDING TOOL 500434
COIL FORMING TOOL
WIRE
MAGNET WIRE
INSTALL SPOOLS IN TENSION ASSY
APPLY MATRIX RESIN
MATRIX RESIN
VITEL VDE
IN SOLVENTS
INSULATOR RESIN
VITON
HOUSING AND STACK COMPONENTS (FROM PART 2, PAGE 3-3)
GENERATOR COMPONENTS (FROM PART 3, PAGE 3-4)



3-1. Stator/Housing Fabrication Plan (Part 1)

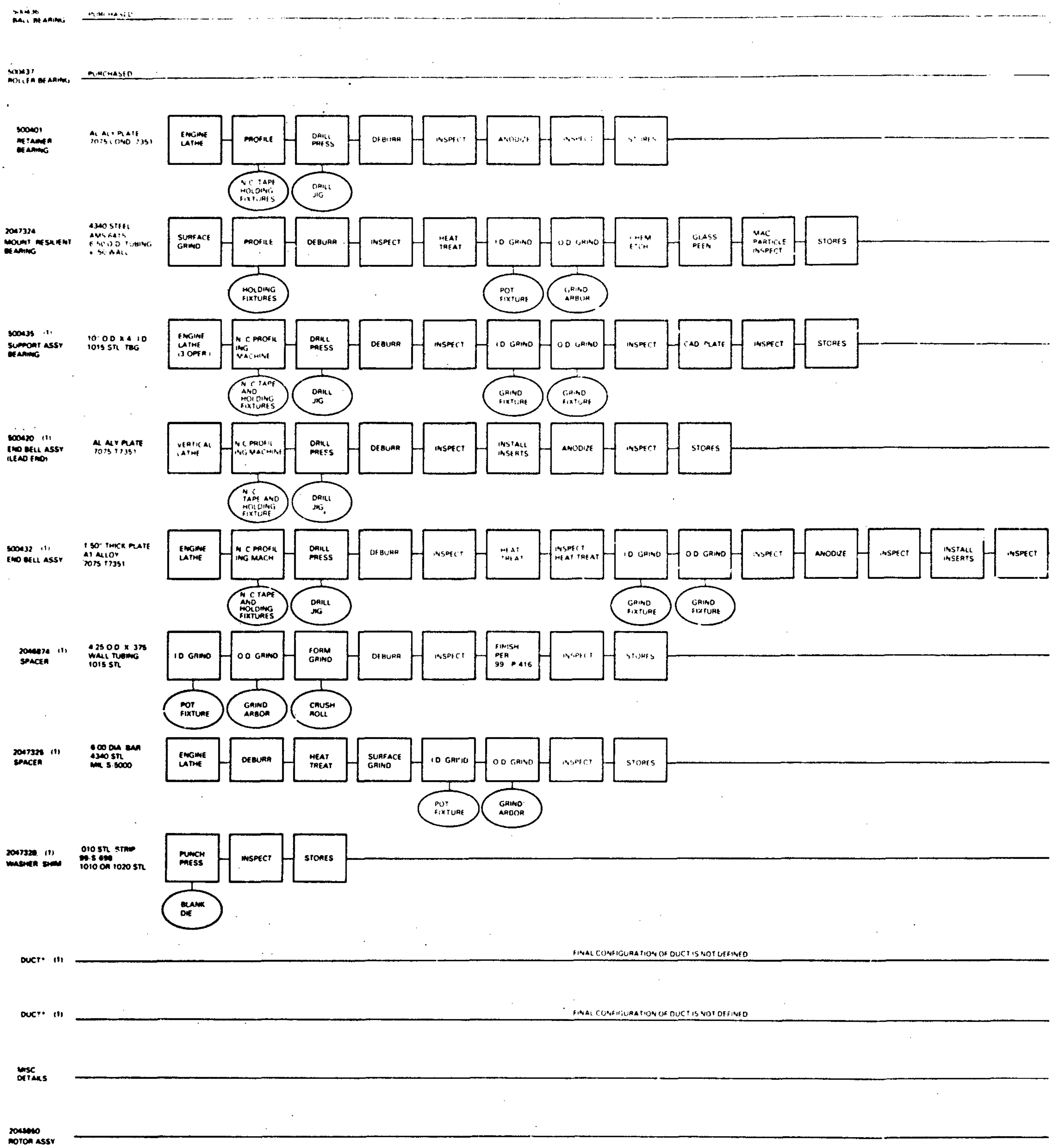
2


500433 (2) SUPPORT WINDING
NEMA GRADE G11 EPOXY GLASS LAMINATED
MOLDING OPERATION
LATHE
INSPECT
STORES
MOLD
LATHE FIXTURE
500439 (1) RING NEUTRAL
AL ALY PLATE 6061 T6
ENGINE LATHE
DRILL PRESS
DEBURR
INSPECT
INSTALL INSERTS
INSPECT
CHEM FILM
INSPECT
STORES
DRILL JIG
500438 1 (10) INSULATOR NEUTRAL RING
NEMA GRADE G11 EPOXY GLASS LAMINATED
MOLD PER PRINT
DRILL PRESS
INSPECT
STORES
COMPRESSION MOLD
DRILL JIG
500438 2 (2) INSULATOR NEUTRAL RING
NEMA GRADE G11 EPOXY GLASS LAMINATED
MOLD PER PRINT
DRILL PRESS
INSPECT
STORES
COMPRESSION MOLD
DRILL JIG
500401 1 (21) INSULATOR
500422 (1) BORE SEAL ASSY
ASSEMBLY BENCH
OVEN (BAKE)
ASSEMBLY BENCH
INSPECT
PRESSURE OR LEAK TEST
STORES
GLASS CLOTH
MISC DETAILS (1)
500427-1 (42) (42 REQD) TERMINAL ELEC
625 HEX BAR ZIRCONIUM COPPER CDA-150 (HARD)
ENGINE LATHE (4 OPER.)
DEBURR
INSPECT
STORES
500426-1 (42) SLEEVE
NEMA GRADE G11 1 OD DIA BAR
ENGINE LATHE (2 OPER.)
INSPECT
STORES
500426-2 (42) WASHER
NEMA GRADE G11 1 OD DIA BAR
ENGINE LATHE
INSPECT
STORES
TERMINAL DETAILS (42)
PURCHASED

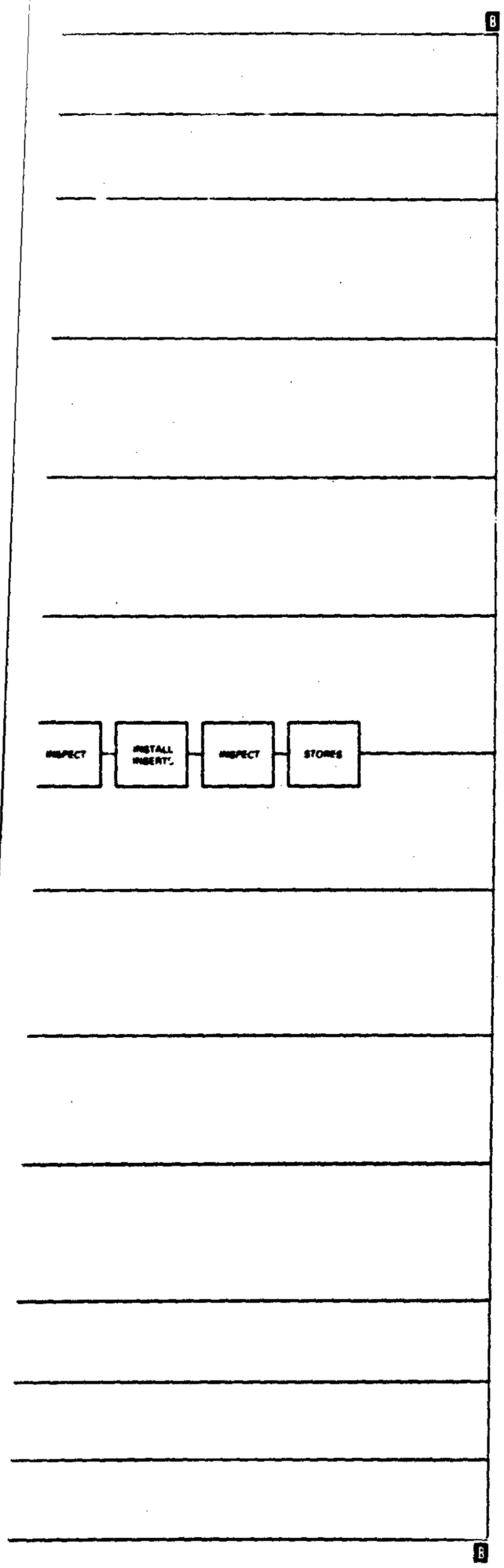


LA-26778

Figure 3-1. Stator/Housing Fabrication Plan
(Part 2 Inserts at A of Part 1)



BALL BEARING
PURCHASED
500437
ROLLER BEARING
PURCHASED
500401
RETAINER BEARING
AL ALY PLATE 7075 COND 7351
ENGINE LATHE
PROFILE
DRILL PRESS
DEBURR
INSPECT
ANODIZE
INSPECT
STORES
N C TAPE HOLDING FIXTURES
DRILL JIG
2047324
MOUNT RESILIENT BEARING
4340 STEEL
SURFACE GRIND
PROFILE
DEBURR
INSPECT
HEAT TREAT
I D GRIND
O D GRIND
CHEM ETCH
GLASS PEEN
MAC PARTICLE INSPECT
STORES
HOLDING FIXTURES
POT FIXTURE
GRIND ARBOR
500435 (1)
SUPPORT ASSY BEARING
10 O D X 4 I D 1015 STL TBG
ENGINE LATHE (3 OPER)
N C PROFILING MACHINE
DRILL PRESS
DEBURR
INSPECT
I D GRIND
O D GRIND
INSPECT
CAD PLATE
INSPECT
STORES
N C TAPE AND HOLDING FIXTURES
DRILL JIG
GRIND FIXTURE
GRIND FIXTURE
500420 (1)
END BELL ASSY (LEAD END)
AL ALY PLATE 7075 T7351
VERTICAL LATHE
N C PROFILING MACHINE
DRILL PRESS
DEBURR
INSPECT
INSTALL INSERTS
ANODIZE
INSPECT
STORES
N C TAPE AND HOLDING FIXTURE
DRILL JIG
500432 (1)
END BELL ASSY
1 50" THICK PLATE AL ALLOY 7075 T7351
ENGINE LATHE
N C PROFILING MACH
DRILL PRESS
DEBURR
INSPECT
HEAT TREAT
INSPECT HEAT TREAT
I D GRIND
O D GRIND
INSPECT
ANODIZE
INSPECT
INSTALL INSERTS
INSPECT
N C TAPE AND HOLDING FIXTURES
DRILL JIG
GRIND FIXTURE
GRIND FIXTURE
2046874 (1)
SPACER
4 25 O D X 375 WALL TUBING 1015 STL
I D GRIND
O D GRIND
FORM GRIND
DEBURR
INSPECT
FINISH PER 99 P 416
INSPECT
STORES
POT FIXTURE
GRIND ARBOR
CRUSH ROLL
2047325 (1)
SPACER
6 00 DIA BAR 4340 STL MIL S 5000
ENGINE LATHE
DEBURR
HEAT TREAT
SURFACE GRIND
I D GRIND
O D GRIND
INSPECT
STORES
POT FIXTURE
GRIND ARBOR
2047328 (1)
WASHER SHIM
010 STL STRIP 1010 OR 1020 STL
PUNCH PRESS
INSPECT
STORES
BLANK DIE
DUCT* (1)
FINAL CONFIGURATION OF DUCT IS NOT DEFINED
DUCT* (1)
FINAL CONFIGURATION OF DUCT IS NOT DEFINED
MISC DETAILS
ROTOR ASSY



LA-26778

Figure 3-1. Stator/Housing Fabrication Plan
(Part 3 Inserts at B of Part 1)

2

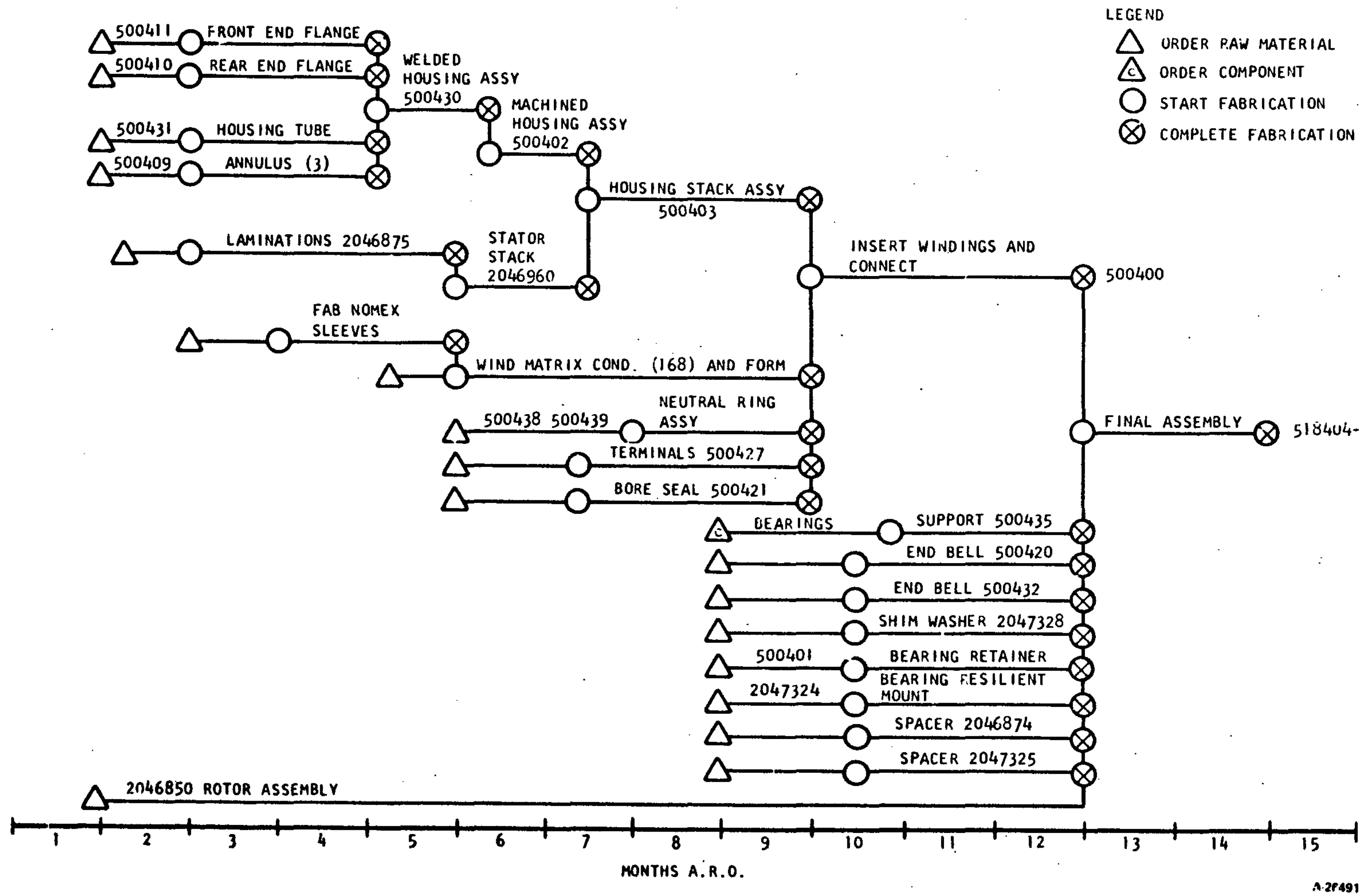
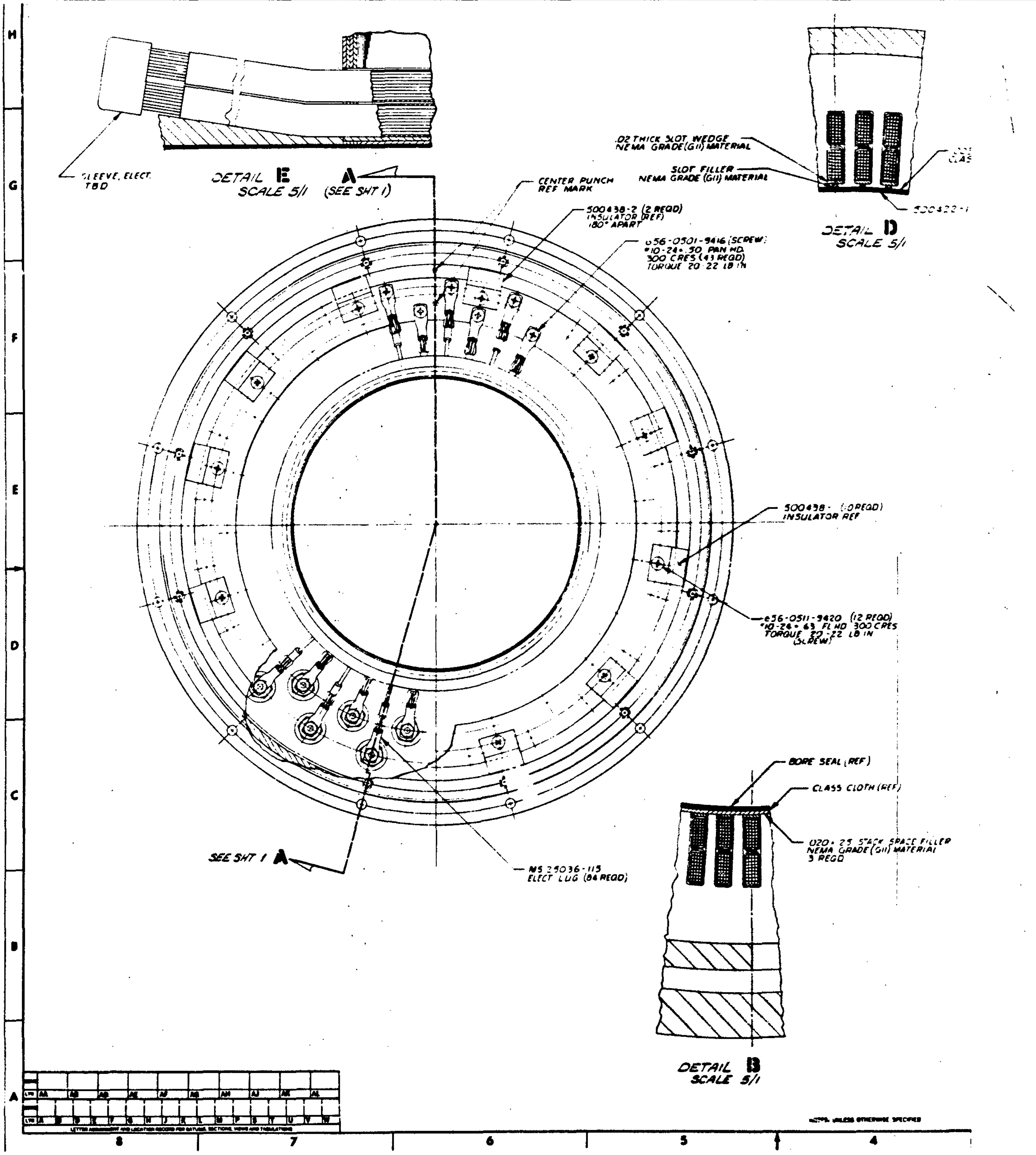
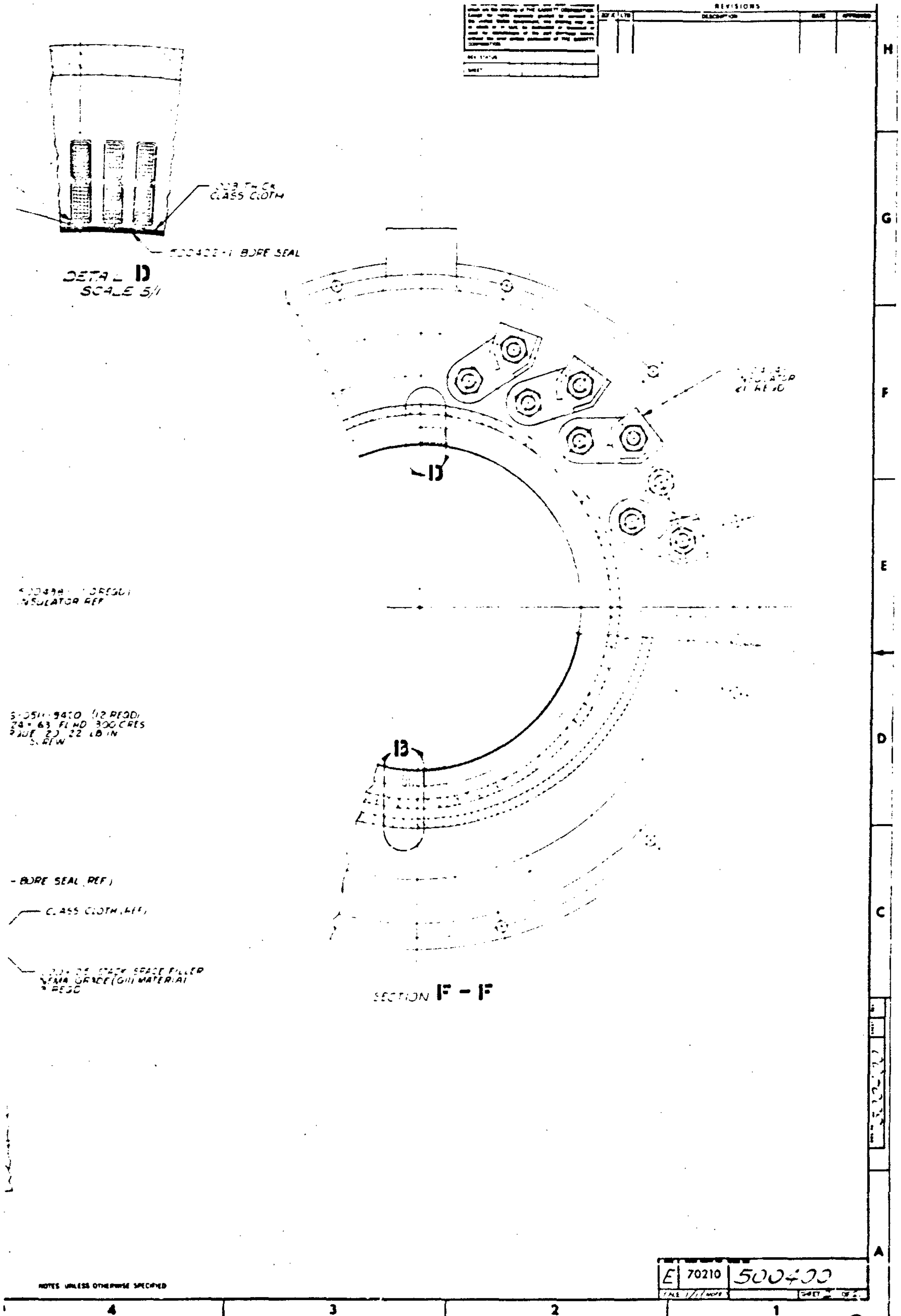


Figure 3-2. Fabrication Schedule

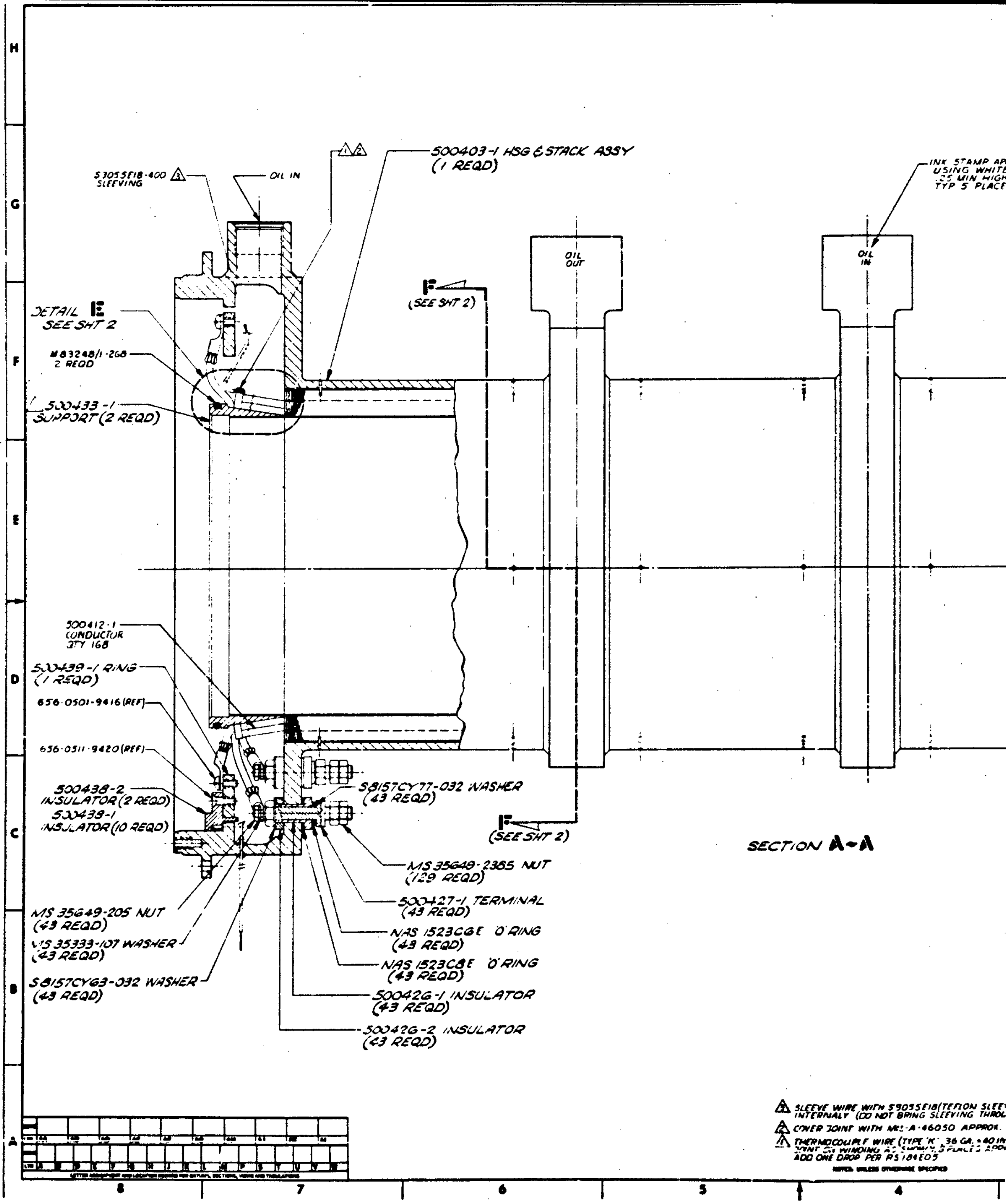
INDEX OF DRAWINGS

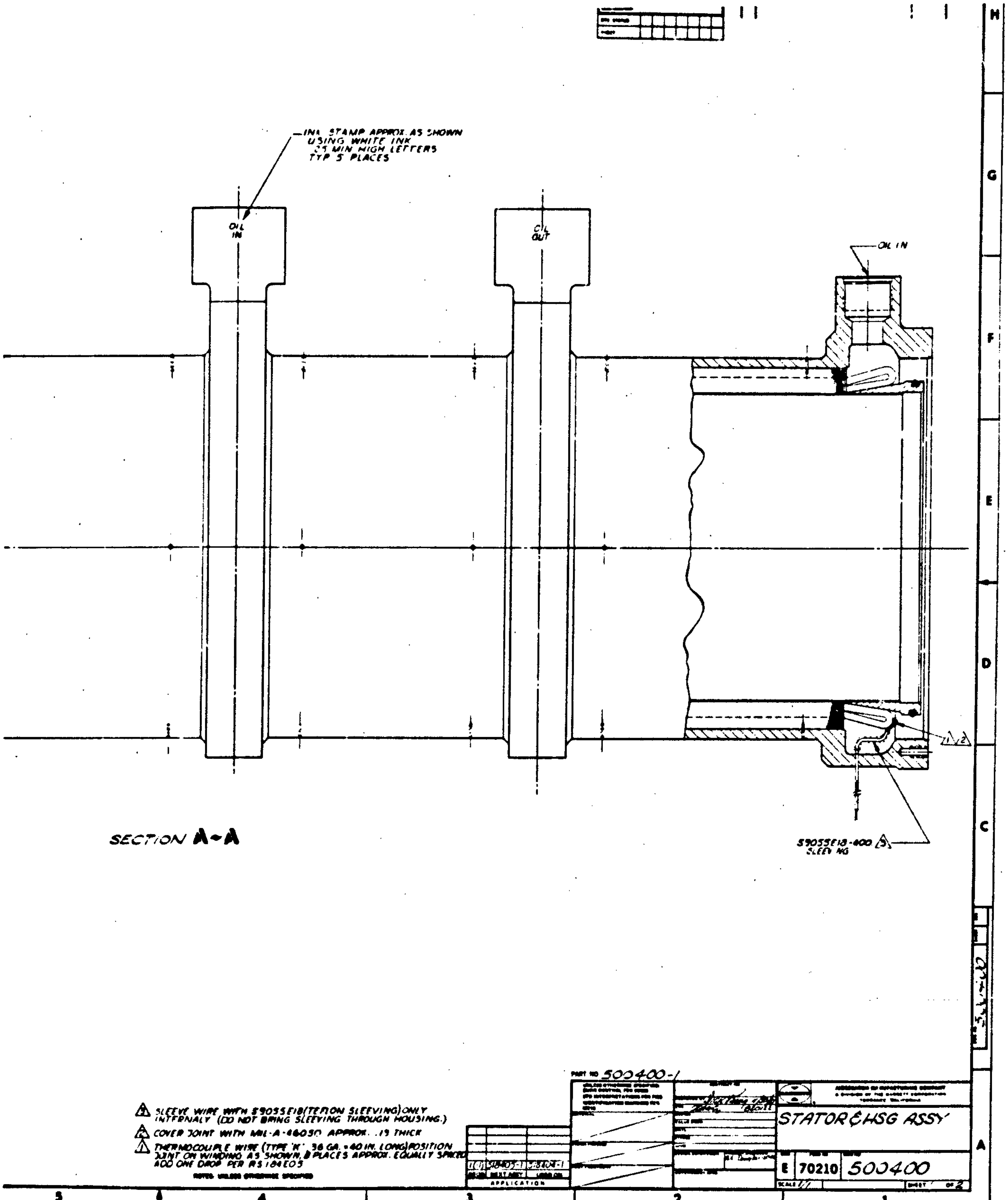
500400	Stator and Housing Assy
500401	Bearing Retainer
500402	Machined Stator Housing
500403	Housing and Stack Assy
500409	Annulus Subassy
500410	Housing Support Subassy
500411	Plate Flange Subassy
500420	End Bell Assy (Lead End)
500421	Bore Seal Fabrication
500422	Bore Seal Assy
500425	Annulus Details
500426	Terminal Insulator
500427	Electrical Terminal
500428	Flanged Terminal Plate
500429	Housing Support
500430	Fabricated Stator Housing
500431	Housing Tube
500432	End Bell Assembly
500433	Bore Seal Support
500434	Winding Assy Form
500435	Bearing Support Assembly
500436	Ball Bearing (Purchased part--not included)
500437	Roller Bearing (Purchased part--not included)
500438	Neutral Ring Insulator
500439	Neutral Ring
518402	Generator System, 10MW
2046855	Balance Weight
2046874	Spacer
2046875	Lamination
2046960	Stator Stack Assy
2047040	Bore Seal Tool End Cap
2047043	Spacer
2047176	Bore Seal Tool Body
2047324	Resilient Bearing Mount
2047325	Spacer
2047328	Shim Washer
2047329	Warning Label
94-3B-0434	Stator Cooling Test
LSK 17367	Stator Cooling Test Rig


SLEEVE, ELECT. TBD
DETAIL E
SCALE 5/1
A (SEE SHT 1)
CENTER PUNCH REF MARK
500438-2 (2 REQD) INSULATOR (REF) 180° APART
656-0501-9416 (SCREW) #10-24 x .50 PAN HD 300 CRES (43 REQD) TORQUE 20-22 LB IN
.02 THICK SLOT WEDGE NEMA GRADE (G11) MATERIAL
SLOT FILLER NEMA GRADE (G11) MATERIAL
DETAIL D
SCALE 5/1
500438- (10 REQD) INSULATOR REF
656-0511-9420 (12 REQD) #10-24 x .63 FL HD 300 CRES TORQUE 20-22 LB IN (SCREW)
BORE SEAL (REF)
GLASS CLOTH (REF)
.020 x .25 STACK SPACE FILLER NEMA GRADE (G11) MATERIAL 3 REQD
SEE SHT 1 A
MS 25036-115 ELECT LUG (84 REQD)
DETAIL B
SCALE 5/1
NOTES: UNLESS OTHERWISE SPECIFIED
H
G
F
E
D
C
B
A
8
7
6
5
4

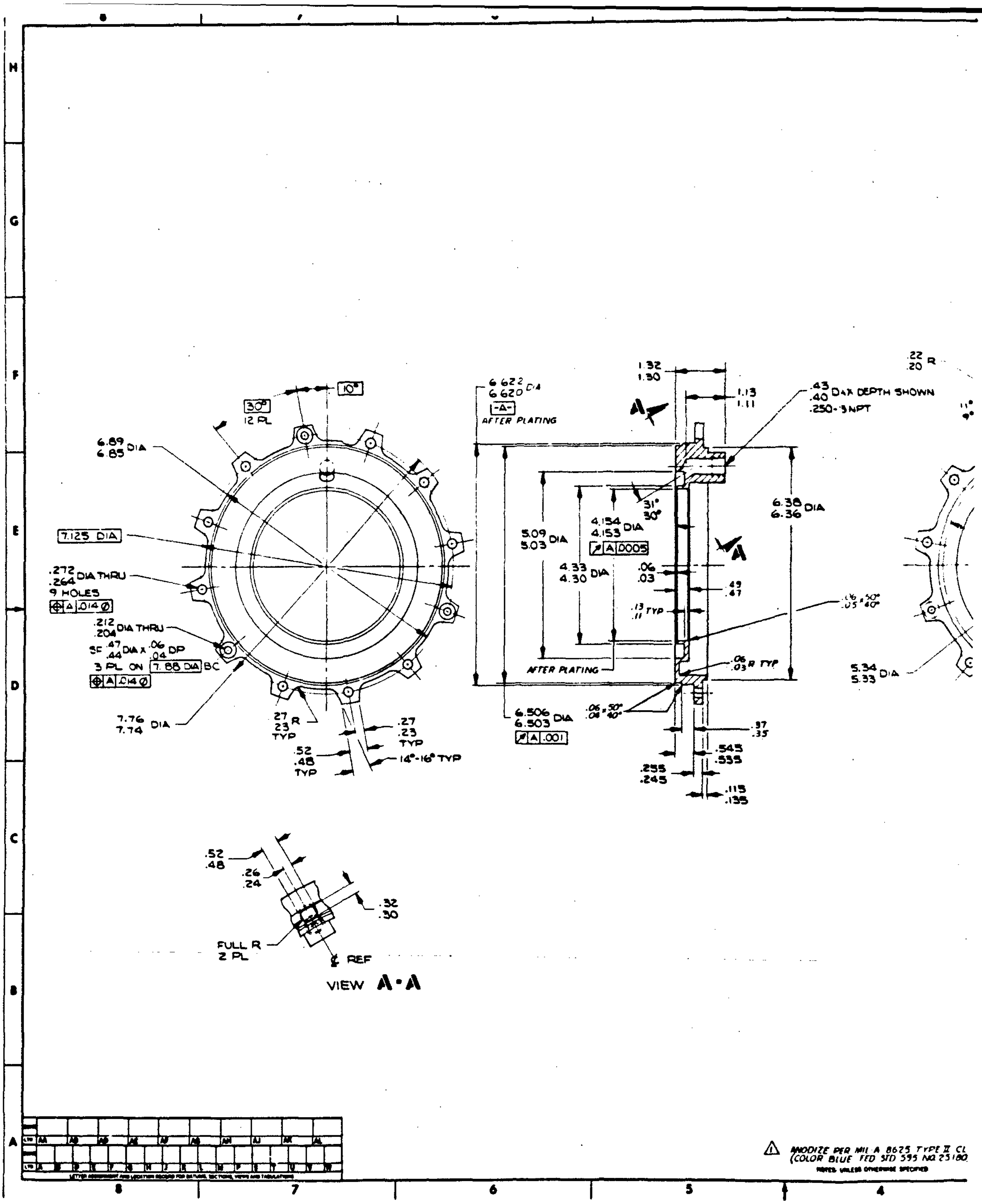


GLASS CLOTH
BORE SEAL
DETAIL D
SCALE 5/1
INSULATOR REF
BORE SEAL (REF)
GLASS CLOTH (REF)
SECTION F - F
NOTES UNLESS OTHERWISE SPECIFIED
E
70210
500400


500403-1 HSG & STACK ASSY
(1 REQD)
S3055F18-400 SLEEVING
OIL IN
INK STAMP
USING WHITE
TYP 5 PLACES
DETAIL E
SEE SHT 2
M83248/1-268
2 REQD
500433-1
SUPPORT (2 REQD)
(SEE SHT 2)
OIL OUT
OIL IN
500412-1
CONDUCTOR
QTY 168
500439-1 RING
(1 REQD)
656-0501-9416 (REF)
656-0511-9420 (REF)
500438-2
INSULATOR (2 REQD)
500438-1
INSULATOR (10 REQD)
S8157CY77-032 WASHER
(43 REQD)
(SEE SHT 2)
SECTION A-A
MS 35649-2385 NUT
(129 REQD)
500427-1 TERMINAL
(43 REQD)
MS 35649-205 NUT
(43 REQD)
MS 35333-107 WASHER
(43 REQD)
NAS 1523C6E O RING
(43 REQD)
NAS 1523C8E O RING
(43 REQD)
S8157CY63-032 WASHER
(43 REQD)
500426-1 INSULATOR
(43 REQD)
500426-2 INSULATOR
(43 REQD)
SLEEVE WIRE WITH S9055F18 (TEFLON SLEE
INTERNALY (DO NOT BRING SLEEVING THROU
COVER JOINT WITH MIL-A-46050 APPROX.
THERMOCOUPLE WIRE (TYPE 'K', 36 GA. =40 IN
ADD ONE DROP PER PS184E05
NOTES: UNLESS OTHERWISE SPECIFIED
H
G
F
E
D
C
B
A
8
7
6
5
4

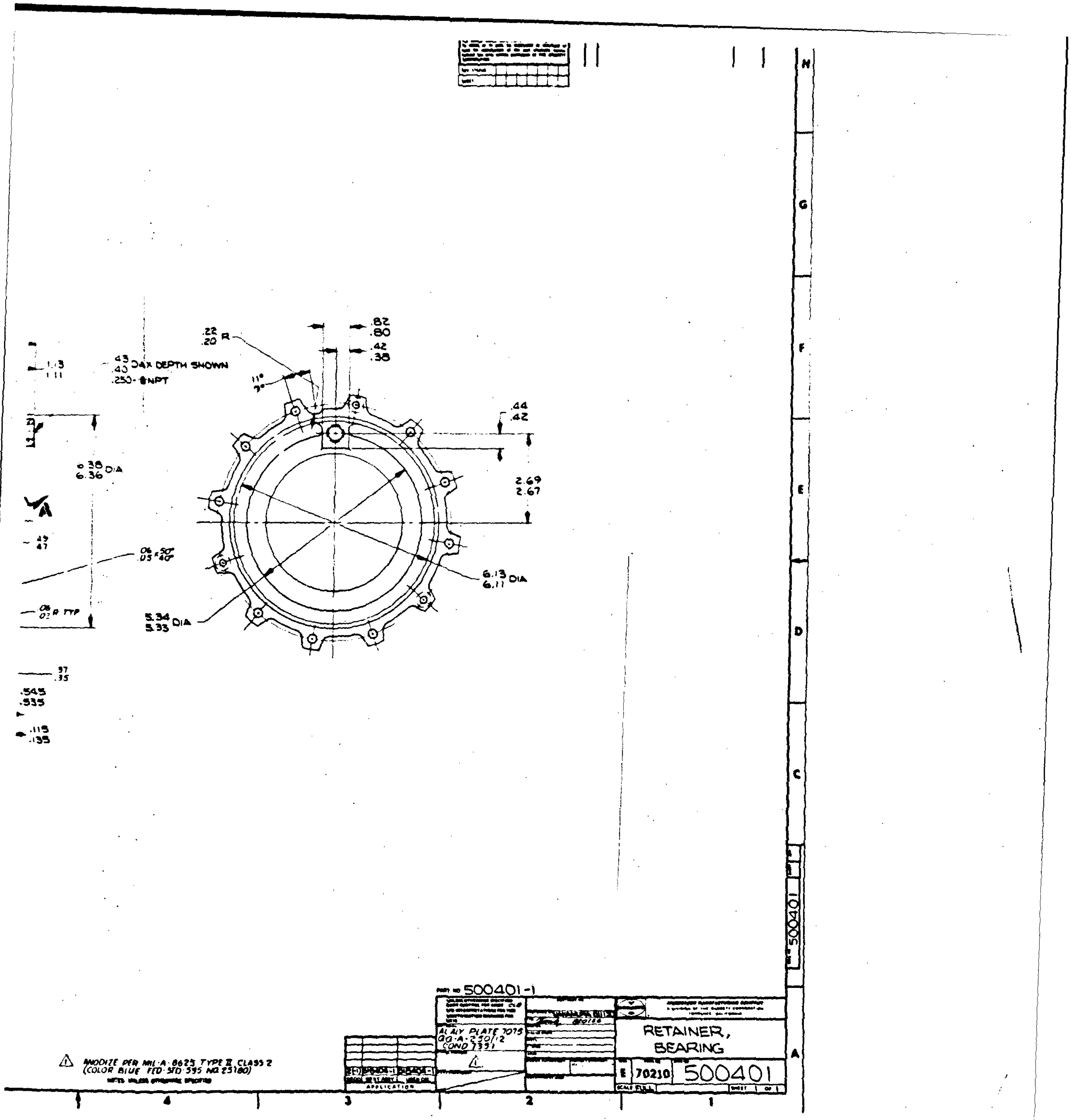


INK STAMP APPROX. AS SHOWN USING WHITE INK .25 MIN HIGH LETTERS TYP 5 PLACES
OIL IN
OIL OUT
OIL IN
SECTION A-A
S9055E18-400 SLEEVING
SLEEVE WIRE WITH S9055E18 (TEFLON SLEEVING) ONLY INTERNALY (DO NOT BRING SLEEVING THROUGH HOUSING.)
COVER JOINT WITH MIL-A-46050 APPROX. .13 THICK
THERMOCOUPLE WIRE (TYPE 'K' 36 GA. ×40 IN. LONG) POSITION JOINT ON WINDING AS SHOWN, 8 PLACES APPROX. EQUALLY SPACED ADD ONE DROP PER RS184E05
NOTES: UNLESS OTHERWISE SPECIFIED
APPLICATION
NEXT ASSY
PART NO 500400-1
STATOR & HSG ASSY
E
70210
500400
SCALE 1/1
SHEET 1 OF 2
2

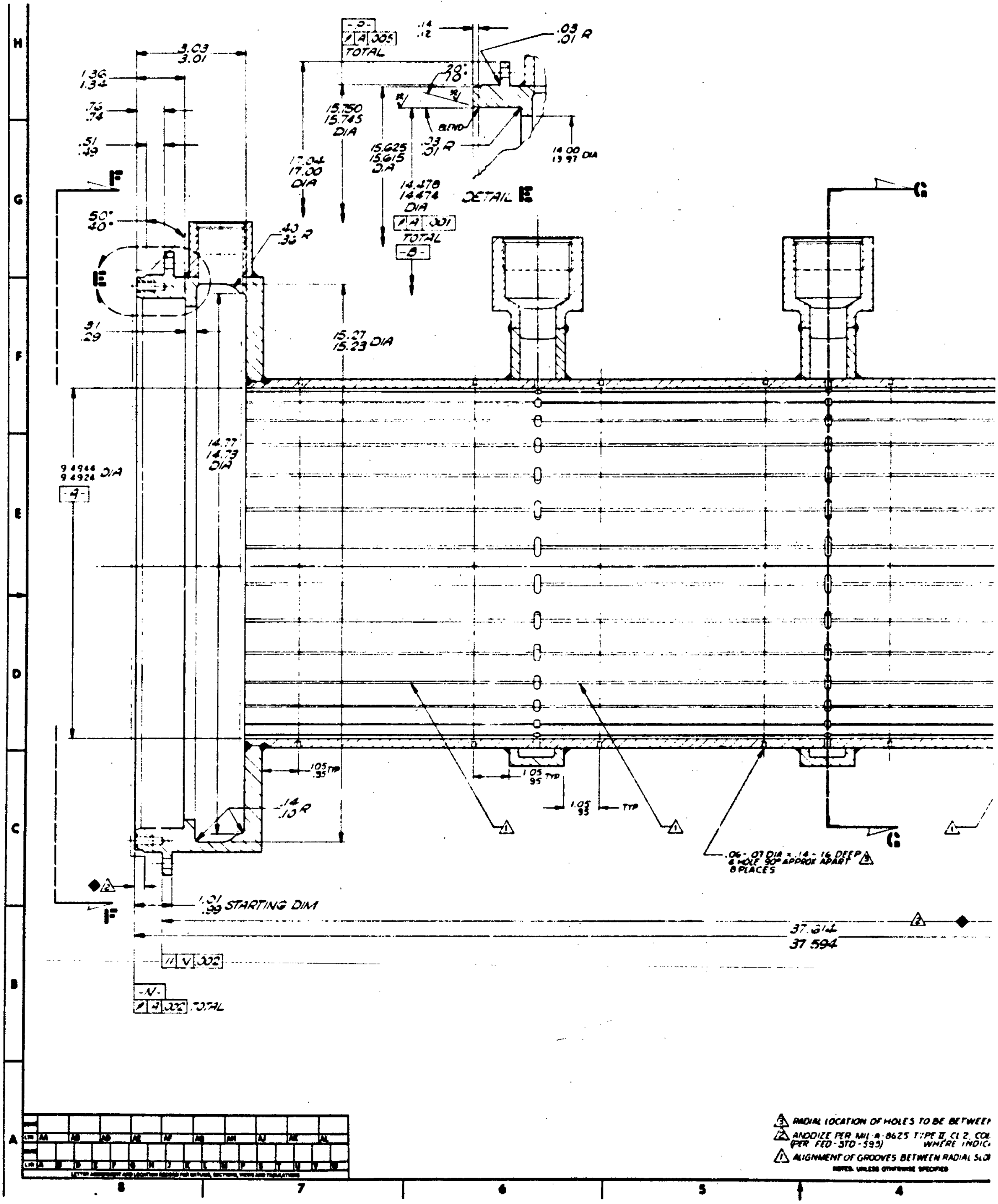


⚠ ANODIZE PER MIL-A-8625 TYPE II CL
(COLOR BLUE FED STD 595 NO 25180

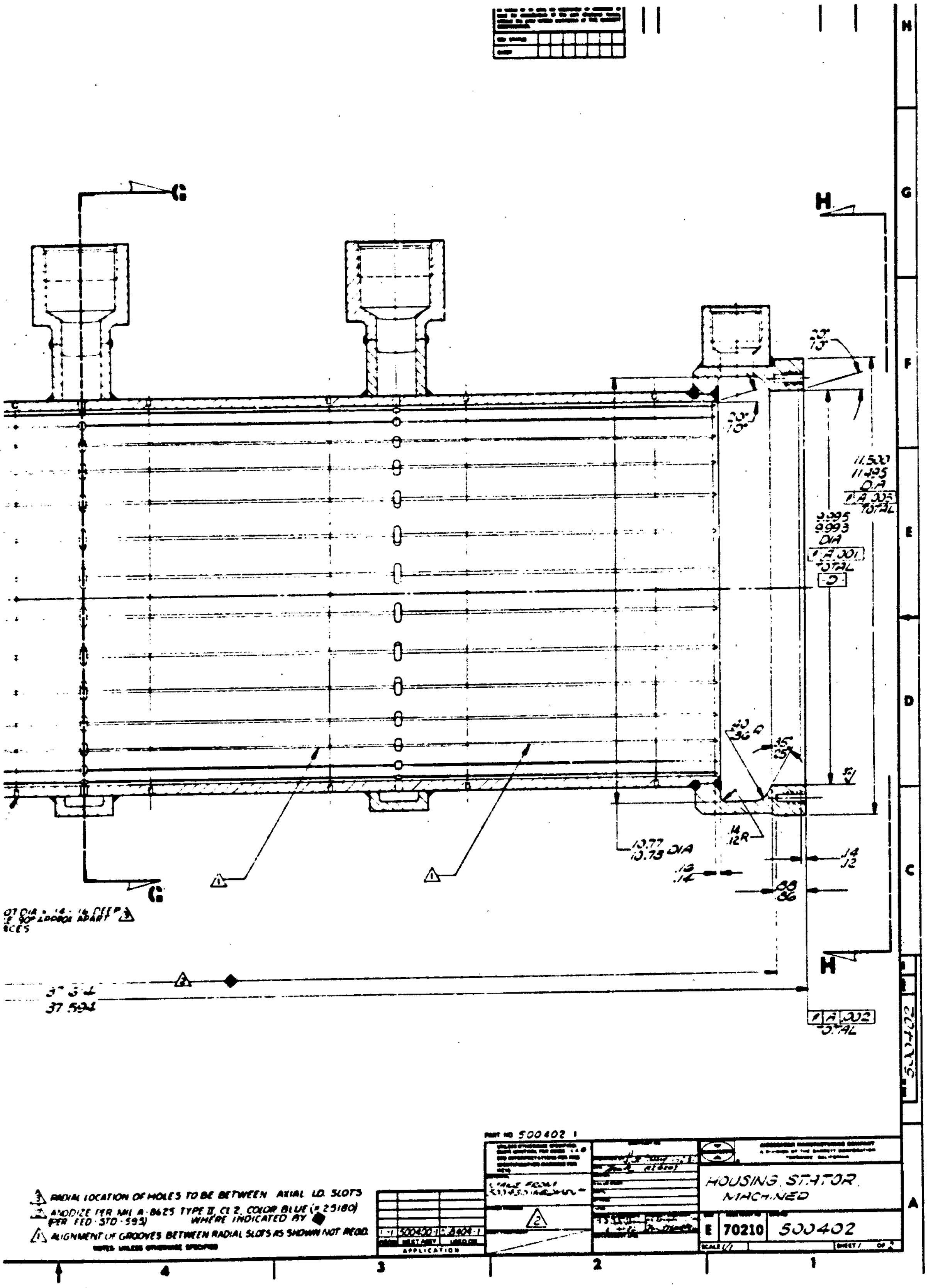
NOTES: UNLESS OTHERWISE SPECIFIED


.22
.20 R
.82
.80
.42
.38
11°
9°
.43
.40 DAX DEPTH SHOWN
.250-18NPT
1.13
1.11
.44
.42
6.38
6.36 DIA
2.69
2.67
A
.49
.47
.06
.05 x 50°
40°
6.13
6.11 DIA
.06
.02 R TYP
5.34
5.33 DIA
.37
.35
.545
.535
.115
.135
500401
PART NO 500401-1
AL ALY PLATE 7075
QQ-A-250/12
COND 7351
RETAINER,
BEARING
E
70210
500401
SCALE FULL
APPLICATION
ANODIZE PER MIL-A-8625 TYPE II CLASS 2
(COLOR BLUE FED STD 595 NO. 25180)
NOTES: UNLESS OTHERWISE SPECIFIED
H
G
F
E
D
C
A
4
3
2
1

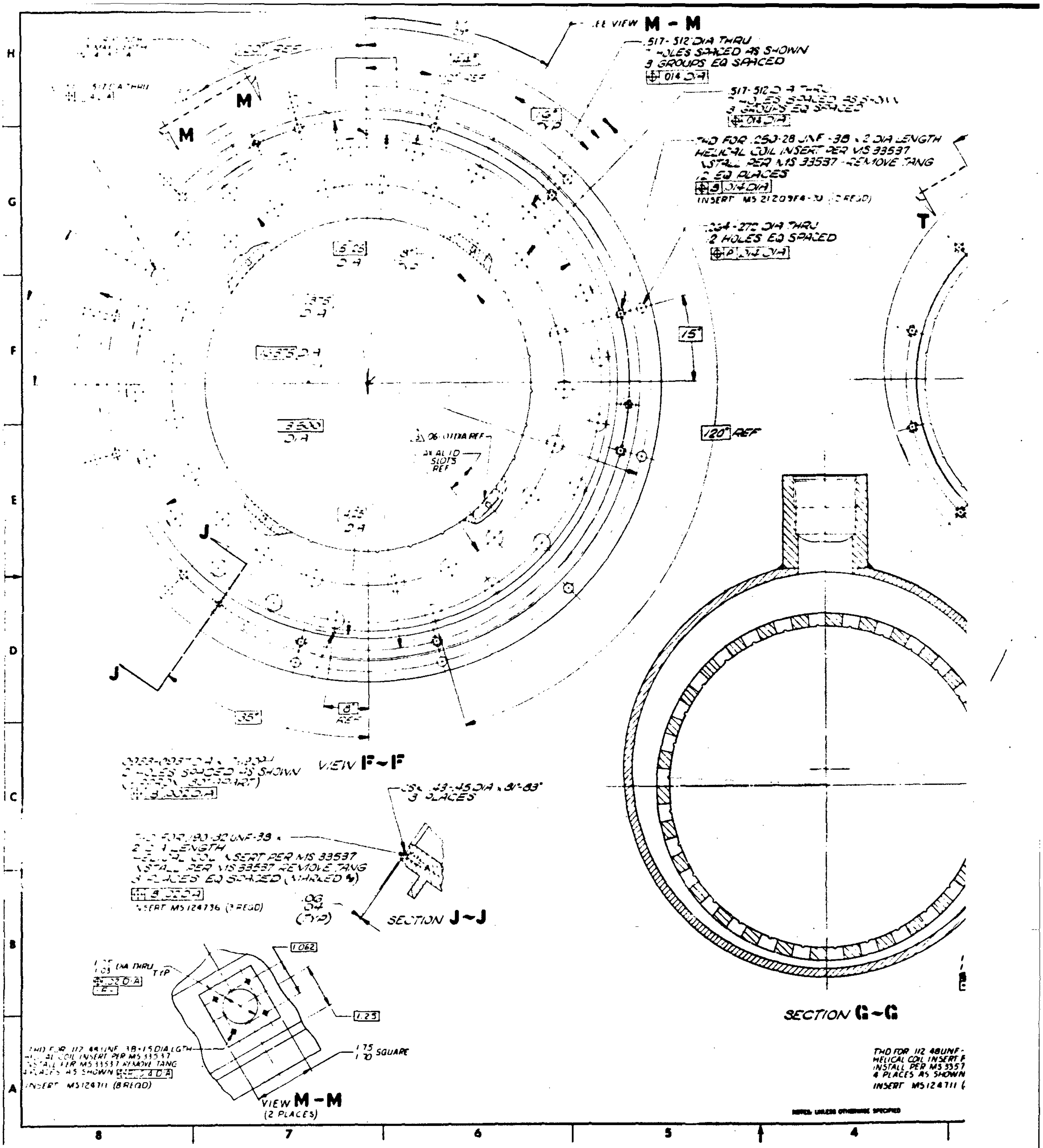
2



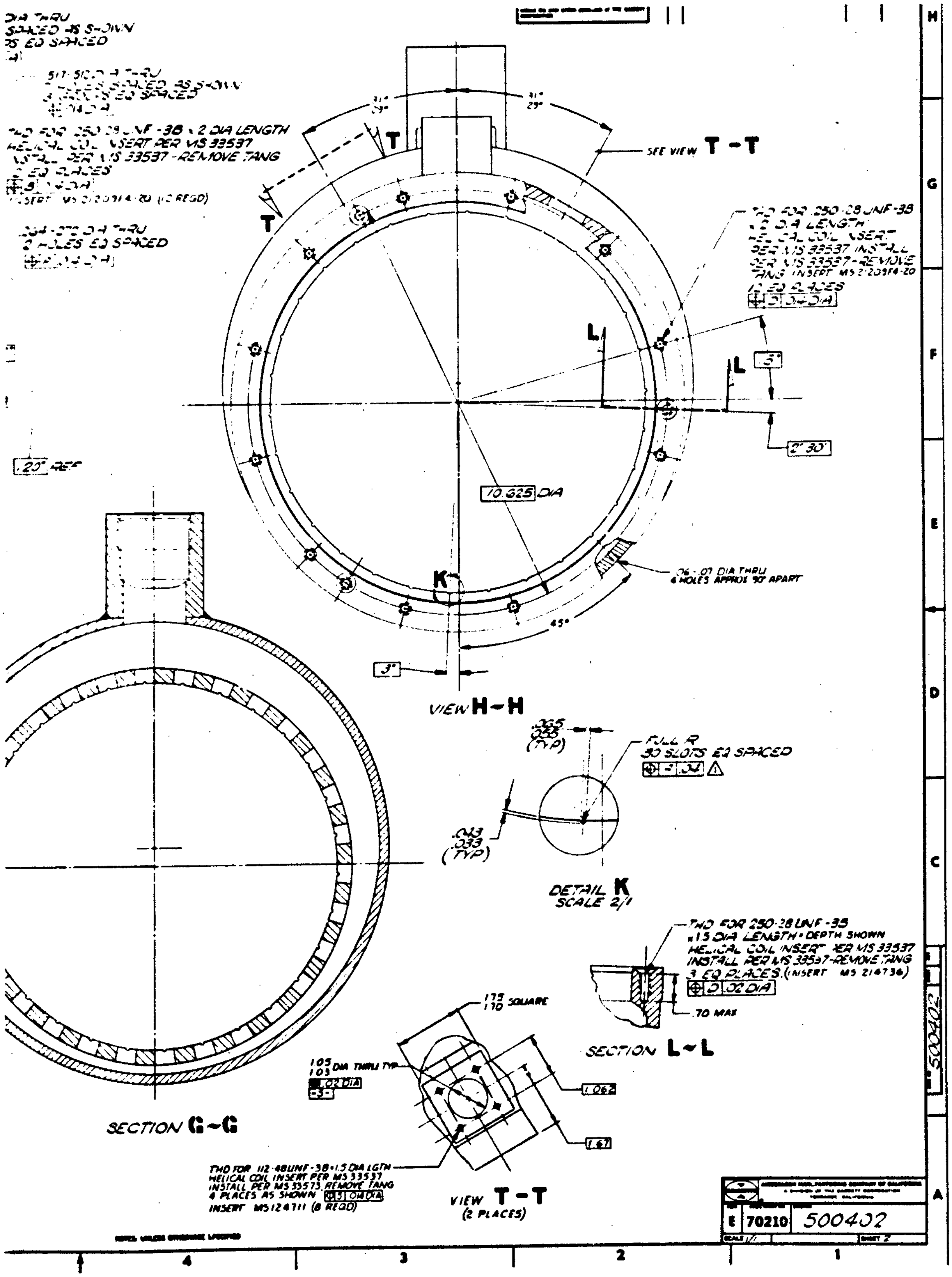
DETAIL E
15.750
15.745
DIA
15.625
15.615
DIA
17.04
17.00
DIA
14.478
14.474
DIA
TOTAL
14.00
13.97 DIA
BLEND
15.27
15.23 DIA
14.77
14.73
DIA
9.4944
9.4924 DIA
3.03
3.01
1.36
1.34
.76
.74
.51
.49
.31
.29
50°
40°
.40
.36 R
.14
.10 R
1.05
.95 TYP
1.01
.99 STARTING DIM
37.614
37.594
.06-.07 DIA x .14-.16 DEEP
4 HOLE 90° APPROX APART
8 PLACES
TOTAL
RADIAL LOCATION OF HOLES TO BE BETWEE
ANODIZE PER MIL-A-8625 TYPE II, CL 2, COL
(PER FED-STD-595) WHERE INDIC
ALIGNMENT OF GROOVES BETWEEN RADIAL SLO
NOTES: UNLESS OTHERWISE SPECIFIED


G
H
11.500
11.495
DIA
10.77
10.73 DIA
9.995
9.993
DIA
D
37.594
3 RADIAL LOCATION OF HOLES TO BE BETWEEN AXIAL I.D. SLOTS
2 ANODIZE PER MIL-A-8625 TYPE II, CL 2, COLOR BLUE (# 25180) (PER FED-STD-595) WHERE INDICATED BY ◆
1 ALIGNMENT OF GROOVES BETWEEN RADIAL SLOTS AS SHOWN NOT REQD.
NOTES: UNLESS OTHERWISE SPECIFIED
PART NO 500402-1
APPLICATION
HOUSING, STATOR, MACHINED
E 70210 500402

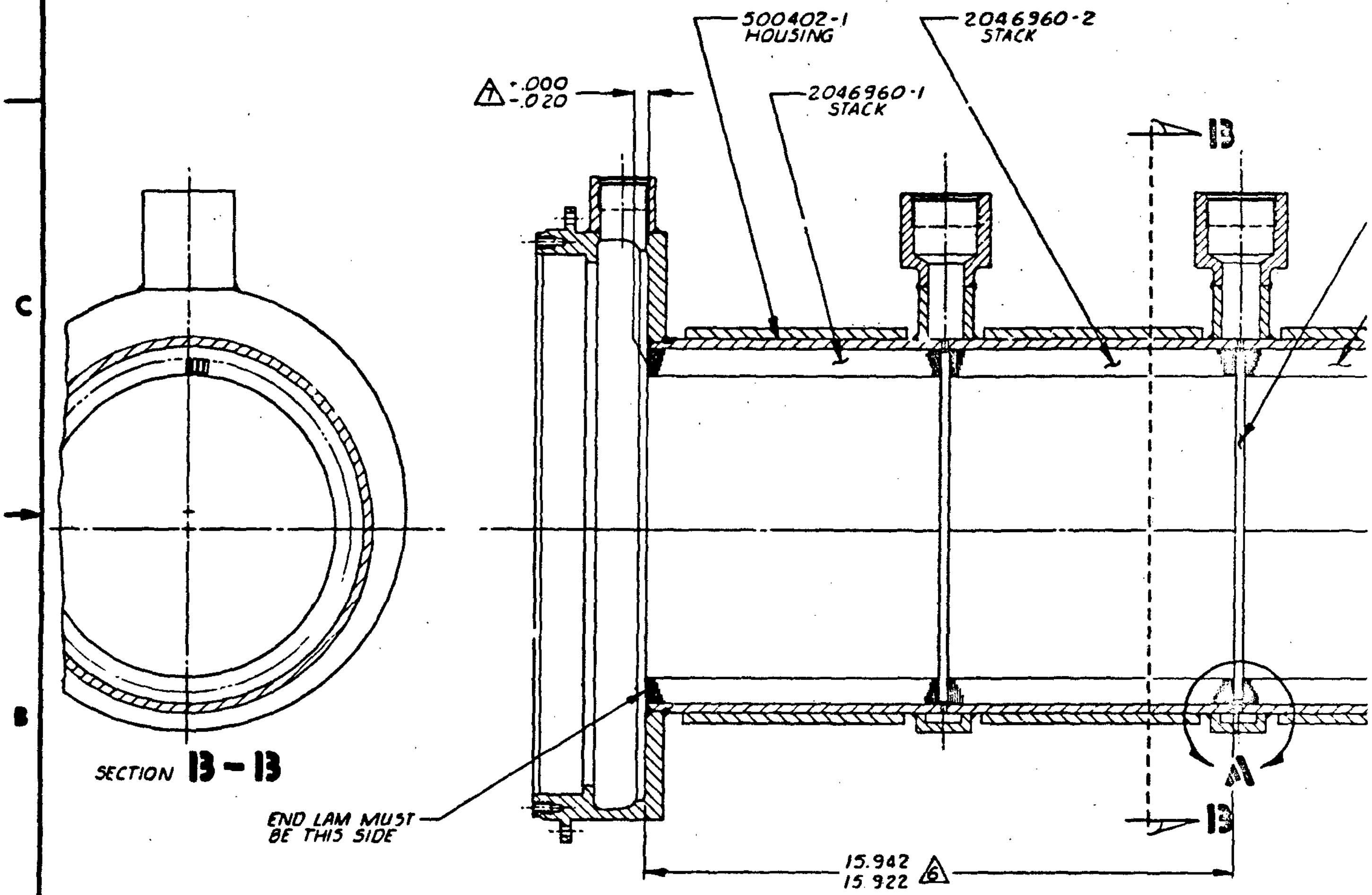
2

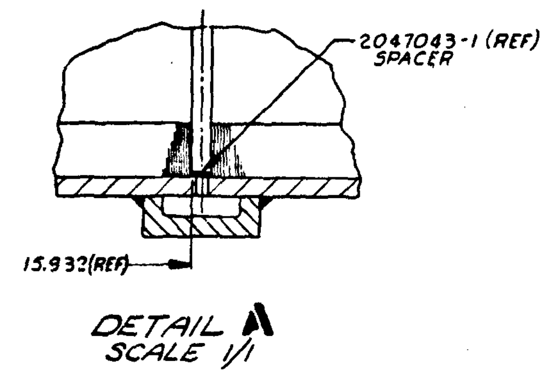


SEE VIEW M - M
.517-.512 DIA THRU
HOLES SPACED AS SHOWN
3 GROUPS EQ SPACED
THD FOR .250-28 UNF-3B x 2 DIA LENGTH
HELICAL COIL INSERT PER MS 33537
INSTALL PER MS 33537 - REMOVE TANG
.264-.272 DIA THRU
2 HOLES EQ SPACED
15°
120° REF
35°
8° REF
VIEW F~F
CSK .43-.45 DIA x 81°-83°
3 PLACES
THD FOR .190-32 UNF-3B x
HELICAL COIL INSERT PER MS 33537
INSTALL PER MS 33537 REMOVE TANG
INSERT MS124736
SECTION J~J
1.062
1.25
1.75
1.70 SQUARE
THD FOR .112-48UNF-3B x .15 DIA LGTH
HELICAL COIL INSERT PER MS 33537
INSTALL PER MS 33537 REMOVE TANG
4 PLACES AS SHOWN
INSERT MS124711 (8 REQD)
VIEW M - M
(2 PLACES)
SECTION G~G
THD FOR .112-48UNF-
HELICAL COIL INSERT
INSTALL PER MS 3357
4 PLACES AS SHOWN
INSERT MS124711
NOTES: UNLESS OTHERWISE SPECIFIED
H
G
F
E
D
C
B
A
8
7
6
5
4


SEE VIEW T - T
10.625 DIA
.06-.07 DIA THRU
4 HOLES APPROX 90° APART
VIEW H - H
FULL R
30 SLOTS EQ SPACED
DETAIL K
SCALE 2/1
THD FOR .250-28 UNF-3B
x 1.5 DIA LENGTH x DEPTH SHOWN
HELICAL COIL INSERT PER MS 33537
INSTALL PER MS 33537-REMOVE TANG
3 EQ PLACES (INSERT MS 214736)
.70 MAX
SECTION L - L
.175 .170 SQUARE
.105 .103 DIA THRU TYP
SECTION G - G
THD FOR .112-48UNF-3B x 1.5 DIA LGTH
HELICAL COIL INSERT PER MS 33537
INSTALL PER MS 33573, REMOVE TANG
4 PLACES AS SHOWN
INSERT MS124711 (8 REQD)
VIEW T - T
(2 PLACES)
E 70210 500402

2 3-19/3-20





DETAIL A
SCALE 1/1

7 IF ALL 4 STACKS ARE INSTALLED AT ONE TI[illegible]
THIS DIMENSION MUST BE USED.

6 IF ONE STACK AT A TIME IS INSTALLED T[illegible]
LOCATING DIMENSION MUST BE USED.

5 A BLANKET MAY BE USED TO COVER THE
HEATERS TO RETAIN THE HEAT.

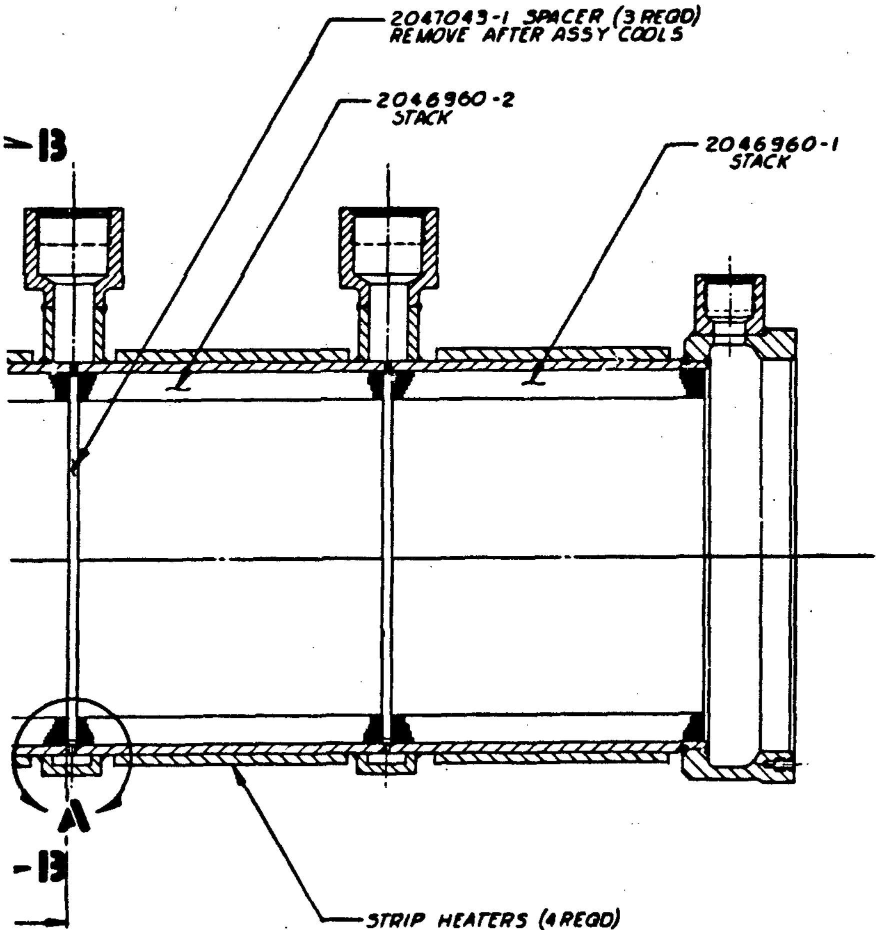
4 STATOR SLOTS MUST BE IN LINE THRU ALL [illegible]
STACKS, A DRILL ROD OR CENTERLESS GROUN[illegible]
CAN BE USED FOR ALIGNING TOOL, A MIN[illegible]
OF 3 RODS MUST BE USED

3 HEATING THE THE HOUSING (P/N 500402-1)
310°F ± 20°F BY USING STRIP HEATERS CO[illegible]
TROLLING THE TEMP WITH A THERMOSTAT [illegible]

2 FOR VISUAL INSPECTION OF STACK ALIGN[illegible]
IN RESPECT TO THE OIL SLOTS IN THE HOUS[illegible]
CAN BE SEEN THRU THE PORTS.

1 PARTS MUST BE SET UP AND PREALIGNED I[illegible]
FIXTURE PRIOR TO ASSY.

NOTES UNLESS OTHERWISE SPECIFIED



'STALLED AT ONE TIME
T BE USED.

E IS INSTALLED THIS
MUST BE USED.

SED TO COVER THE
THE HEAT.

IN LINE THRU ALL 4
CENTERLESS GROUND ROD
NING TOOL, A MIN.
USED.

NING (P/N 500402-1) TO
STRIP HEATERS (CON-
TH A THERMOSTAT OR OVEN.

OF STACK ALIGNMENT
SLOTS IN THE HOUSING
HE PORTS.

ND PREALIGNED IN A
Y.

PECIFIED

1-1	500400-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

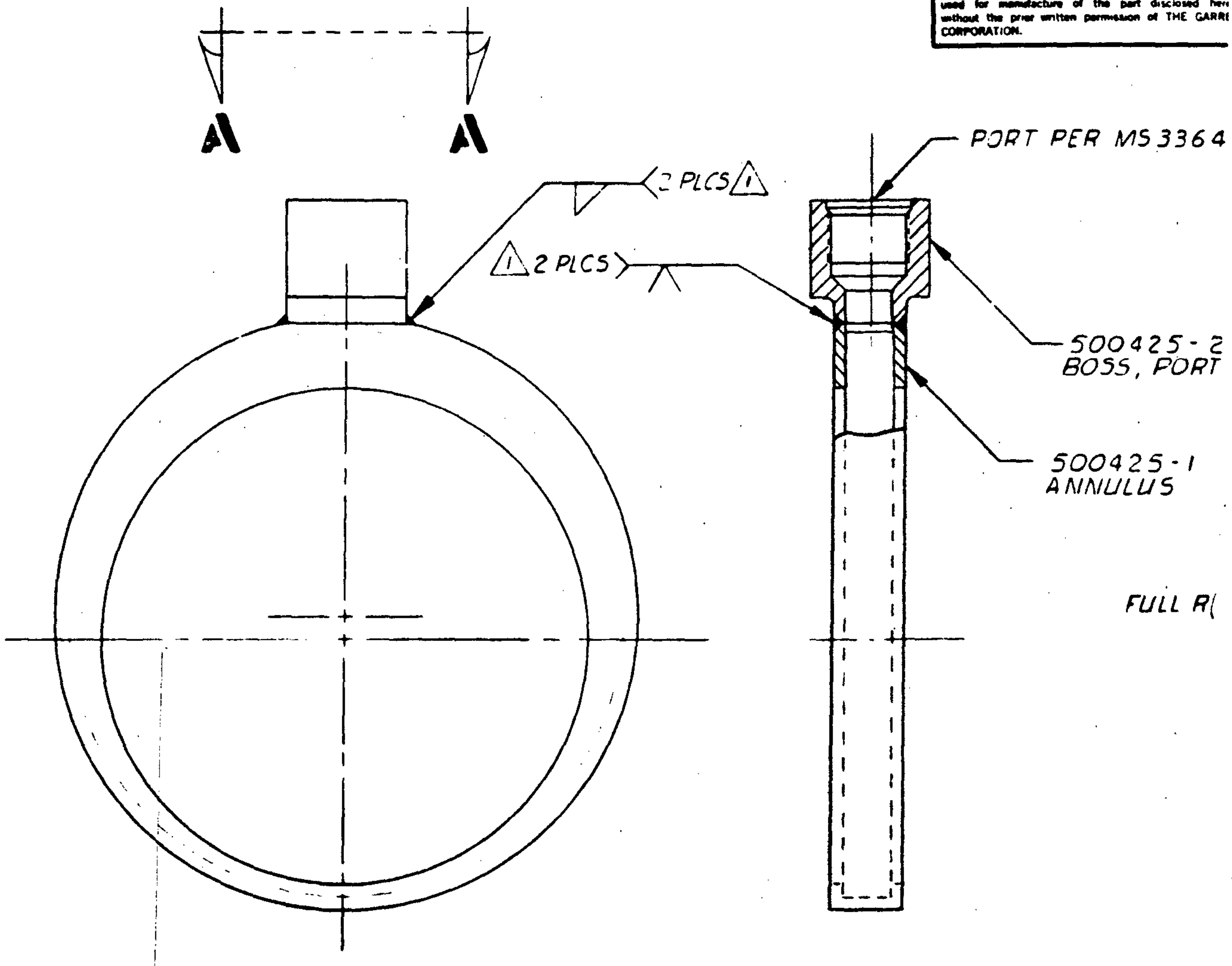
PART NO. 500403-1

HOUSING & STACK
SUB ASSEMBLY

SIZE	CODE IDENT NO	DWG NO
D	70210	500403

SCALE 1/2:1 SHEET 1 OF 1

3-21/3-22 2



PART NO. 500409-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC663 CLB
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER
MC16

MATERIAL

FINISH PROCESS

HEAT TREATMENT

PREPARED
CHK
DESIGN
VALUE E
MATL
STRESS
APVD
DESIGN
GOVERN

3(-1)	500430-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

2. LOCATE BOSS ON FLAT PROVIDED ON MATING PART & WELD AS SHOWN.

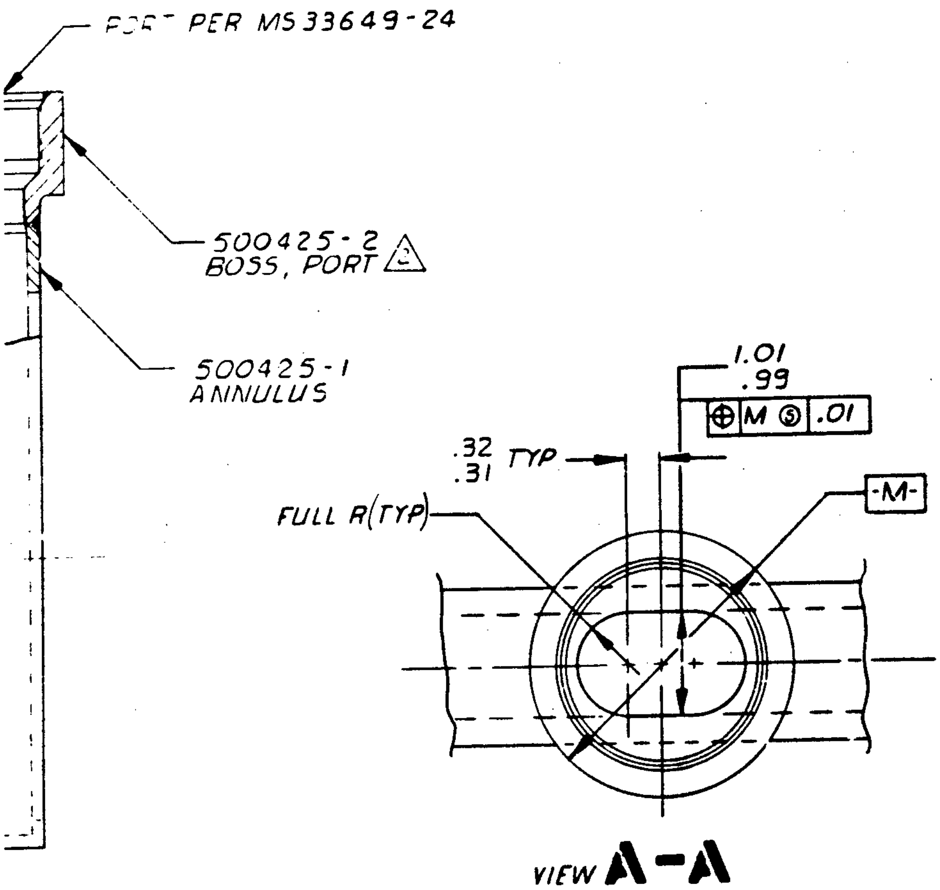
1. WELD PER AIRESEARCH SPEC WBS18

NOTES: UNLESS OTHERWISE SPECIFIED

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

R



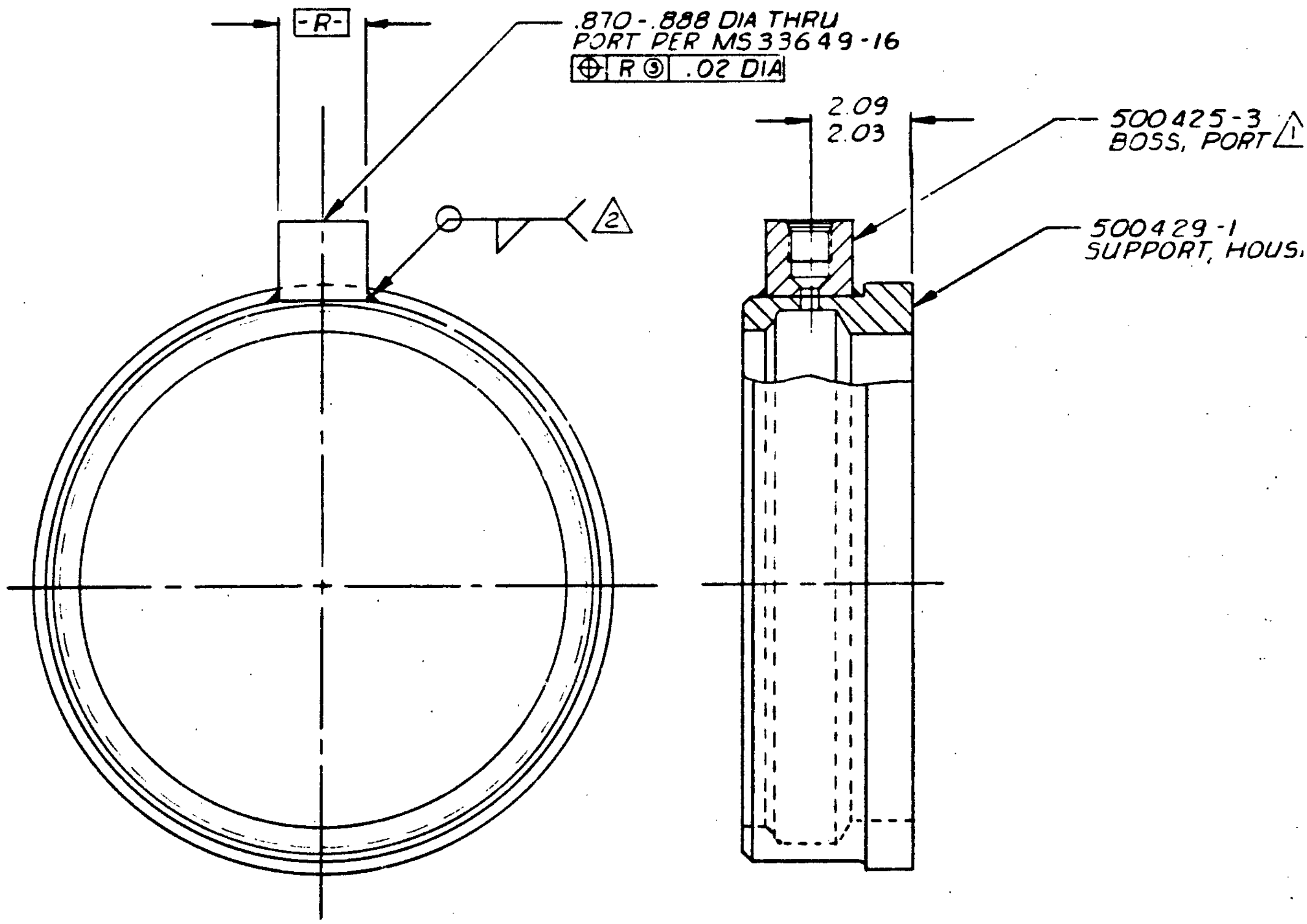
500409

PART NO. 500409-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC853 CLB STD INTERPRETATIONS PER P186 IDENTIFICATION MARKING PER MC16	CONTRACT NO	AIRESEARCH MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA
MATERIAL	PREPARED BY 820114	ANNULUS. SUB. ASSY
	CHK	
	DESIGN	
	VALUE ENGR	
	MATL	
	STRESS	
FINISH PROCESS	APVD	
	DESIGN SUPERVISOR 1-18-82 / PROJECT ENGINEER 1-18-82	SIZE C / CODE IDENT NO 70210 / DWG NO 500409
HEAT TREATMENT	GOVERNMENT APVD	SCALE 1/2 / SHEET 1 OF 1

2

3-23/3-24



PART NO. 500410-1

1(-1)	500430-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC663 CL B
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER MC18

MATERIAL

FINISH PROCESS

HEAT TREATMENT

PREPARED BY
CHK
DESIGN
VALUE ENGR
MATL
STRESS
APVD
DESIGN SUPERV
GOVERNMENT AP

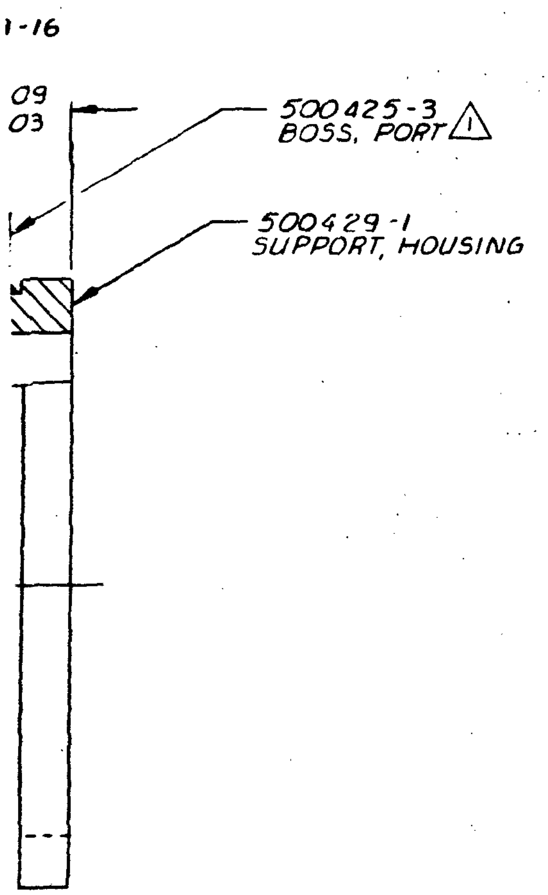
2 LOCATE BOSS ON FLAT PROVIDED ON MATING PART & WELD AS SHOWN.

1 WELD PER AIRESEARCH SPEC WBS18

NOTES: UNLESS OTHERWISE SPECIFIED

REVISIONS

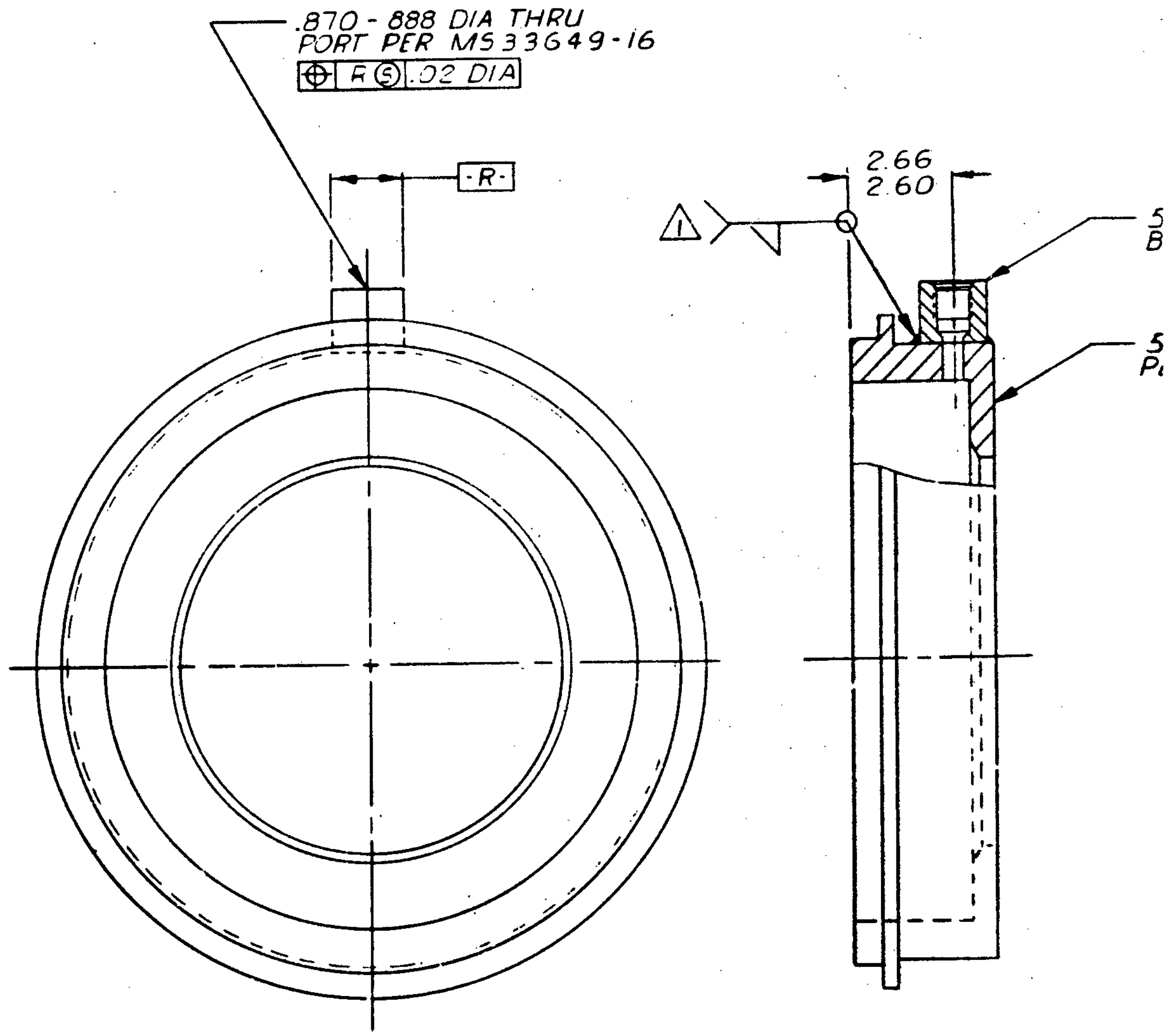
ZONE	LTR	DESCRIPTION	DATE	APPROVED



500410

PART NO. 500410-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC653 CLB STD INTERPRETATIONS PER PI66 IDENTIFICATION MARKING PER MC16	CONTRACT NO PREPARED BY Hardy 820114 CHK DESIGN VALUE ENGR MATL STRESS APVD	AIRESEARCH MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA
MATERIAL		SUPPORT, HOUSING SUB. ASSY
FINISH PROCESS	DESIGN SUPERVISOR 3.3 ... 1-1-72 | PROJECT ENGINEER ...	SIZE C | CODE IDENT NO 70210 | DWG NO 500410
HEAT TREATMENT	GOVERNMENT APVD	SCALE 1/2 | SHEET 1 OF 1



PART NO. 500411-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CLB
STD INTERPRETATIONS PER P185
IDENTIFICATION MARKING PER
MC13

MATERIAL

FINISH PROCESS

HEAT TREATMENT

1(-1)	500430-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

2. LOCATE BOSS ON FLAT PROVIDED ON MATING PART & WELD AS SHOWN.

1. WELD PER AIRESEARCH SPEC WBS18

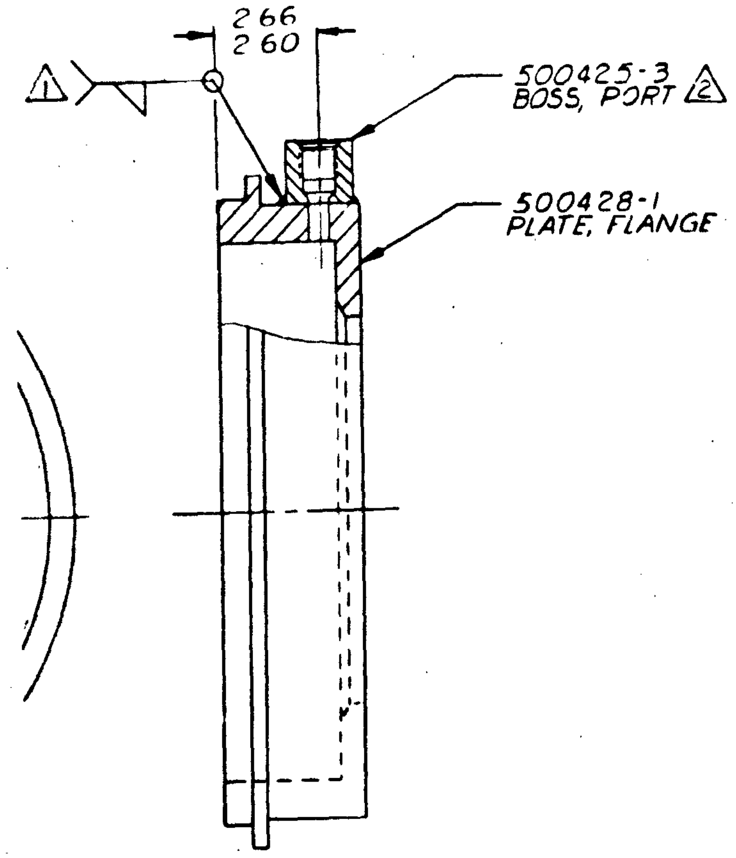
NOTES: UNLESS OTHERWISE SPECIFIED

R

ZONE	LTR	DESCRIPTION	DATE	APPROVED

Caption above the table: REVISIONS

5



500411

PART NO. 500411-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC683 CLB
STD INTERPRETATIONS PER PI88
IDENTIFICATION MARKING PER MC16

MATERIAL

FINISH PROCESS

HEAT TREATMENT

CONTRACT NO

PREPARED BY Kaaty 820114

CHK

DESIGN

VALUE ENGR

MATL

STRESS

APVD

DESIGN SUPERVISOR J.J. ... 1-17-82

PROJECT ENGINEER ...

GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

PLATE, FLANGE
SUB ASSY

SIZE	CODE IDENT NO	DWG NO
C	70210	500411

SCALE NONE SHEET 1 OF 2

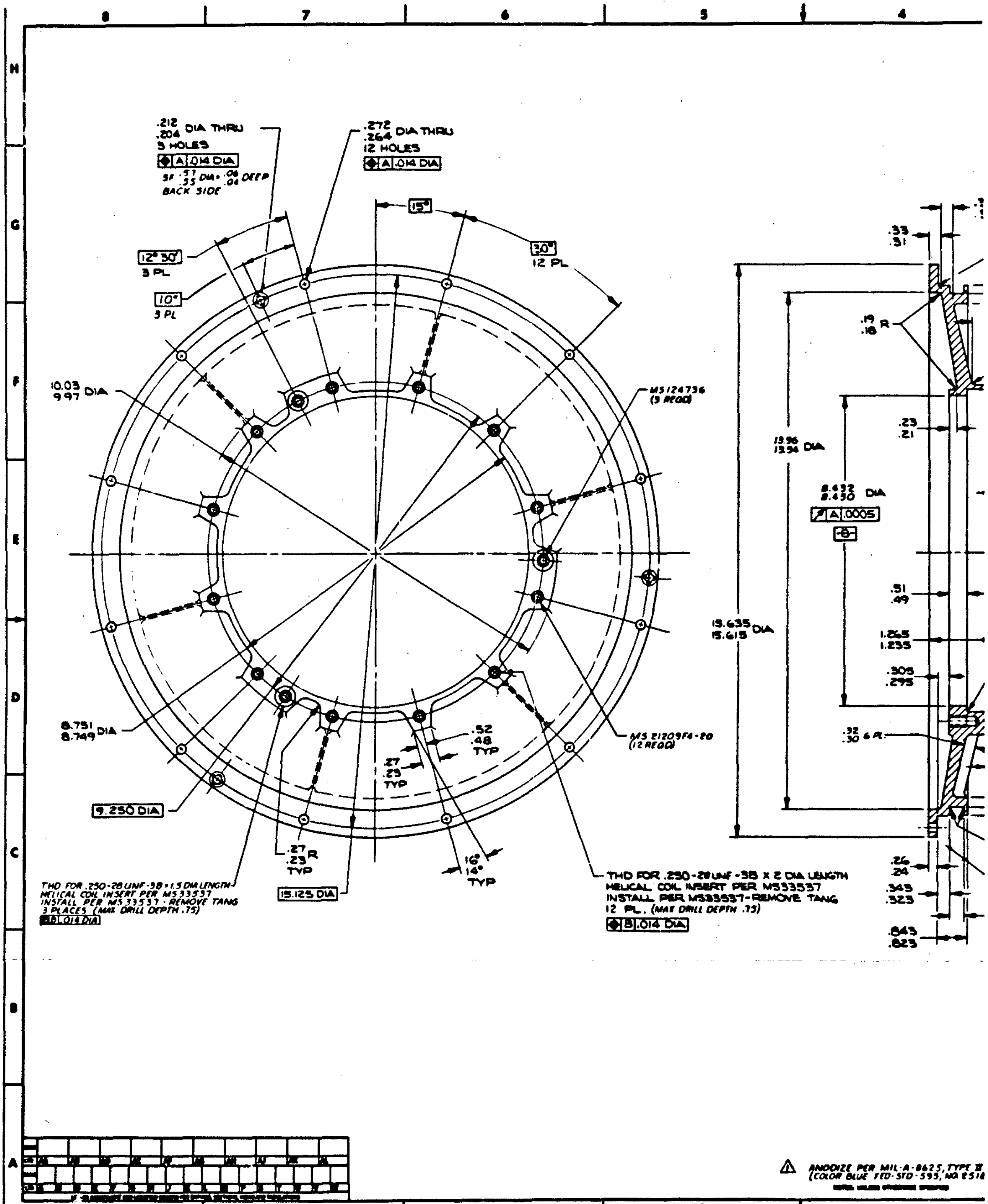
130-1 | 516404-1

ASSY | USED ON

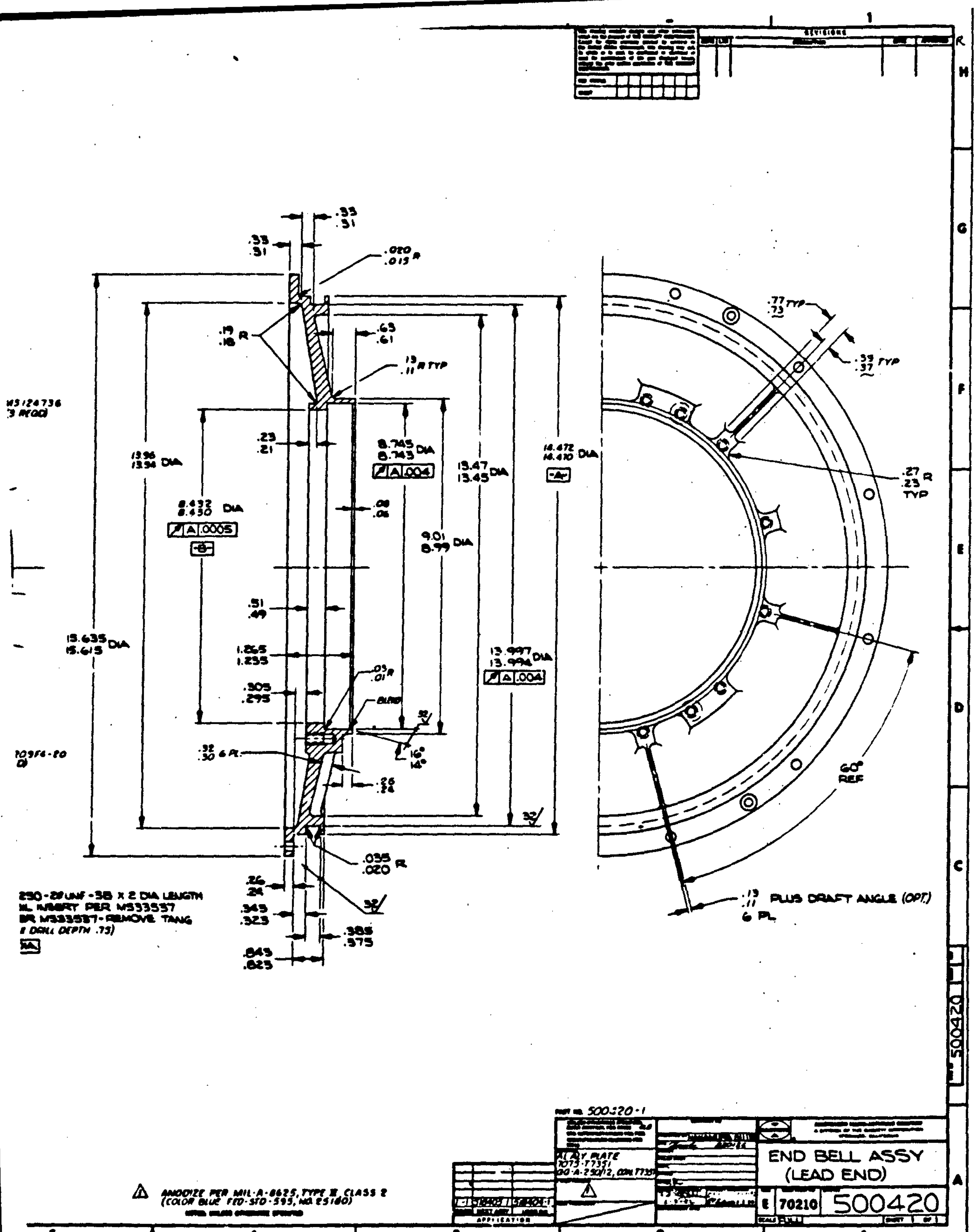
APPLICATION

2

3-27/3-28



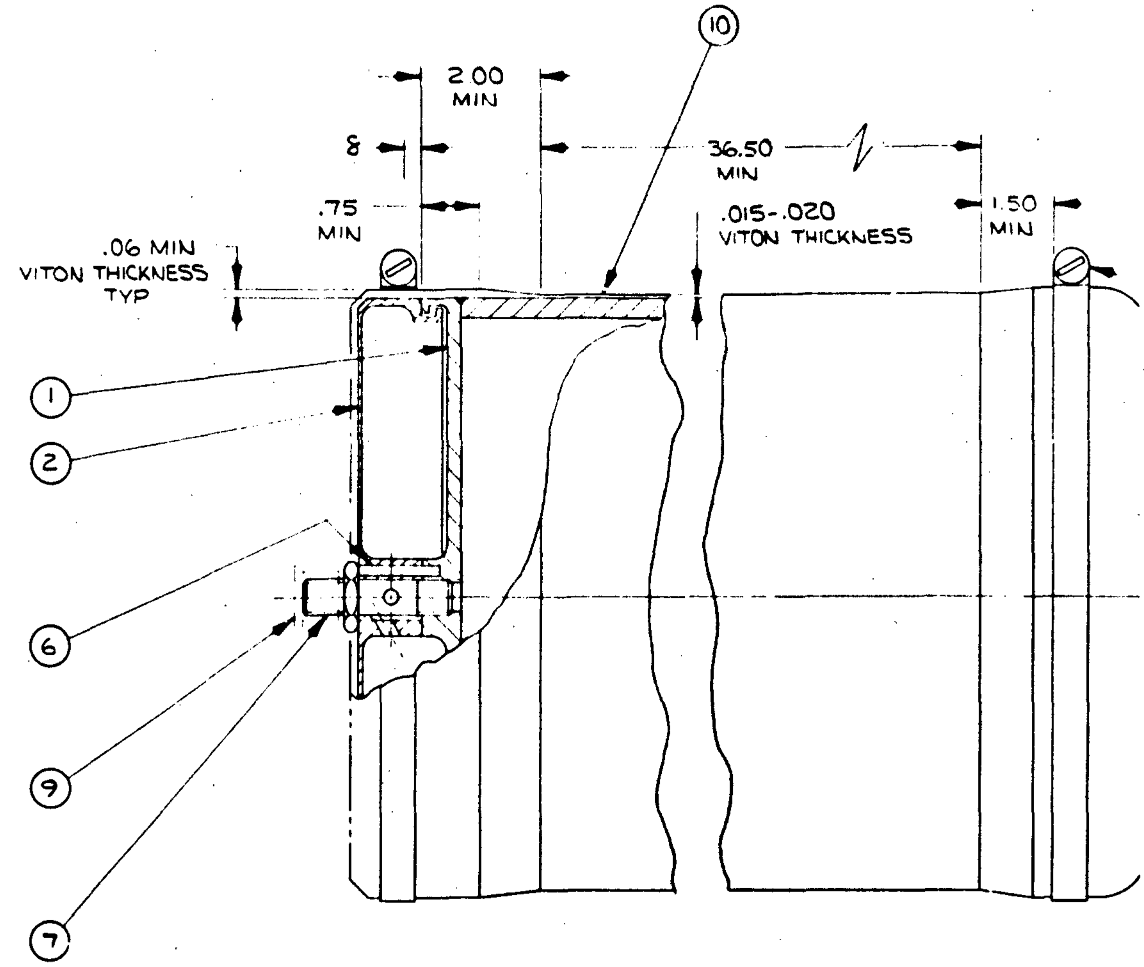
.212
.204 DIA THRU
3 HOLES
A .014 DIA
BACK SIDE
.272
.264 DIA THRU
12 HOLES
A .014 DIA
15°
12° 30'
3 PL
10°
3 PL
30°
12 PL
10.03
9.97 DIA
MS124736
(3 REQD)
8.751
8.749 DIA
MS 21209F4-20
(12 REQD)
.52
.48
TYP
.27
.23
TYP
9.250 DIA
.27
.23 R
TYP
16°
14°
TYP
15.125 DIA
THD FOR .250-28UNF-3B+1.5 DIA LENGTH HELICAL COIL INSERT PER MS33537 INSTALL PER MS33537 - REMOVE TANG 3 PLACES (MAX DRILL DEPTH .75)
THD FOR .250-28UNF-3B X 2 DIA LENGTH HELICAL COIL INSERT PER MS33537 INSTALL PER MS33537-REMOVE TANG 12 PL. (MAX DRILL DEPTH .75)
B .014 DIA
.33
.31
.19
.18 R
.23
.21
13.96
13.94 DIA
8.432
8.430 DIA
A .0005
-B-
.51
.49
15.635
15.615 DIA
1.265
1.255
.305
.295
.32
.30 6 PL
.26
.24
.345
.325
.843
.823
ANODIZE PER MIL-A-8625, TYPE II
(COLOR BLUE FED-STD-595, NO. 2518
H
G
F
E
D
C
B
A
8
7
6
5
4



REVISIONS
.020
.015 R
.19
.16 R
.65
.61
.13
.11 R TYP
.35
.31
MS124736
(3 REQD)
13.96
13.94 DIA
.23
.21
8.745
8.743 DIA
A .004
15.47
15.45 DIA
14.472
14.410 DIA
-A-
8.432
8.430 DIA
A .0005
-B-
.08
.06
9.01
8.99 DIA
.51
.49
15.635
15.615 DIA
1.265
1.235
13.997
13.996 DIA
A .004
.03
.01 R
.305
.295
BURR
.32
.30 6 PL
16°
14°
.26
.24
.035
.020 R
.77 TYP
.73
.39 TYP
.37
.27
.23 R
TYP
60°
REF
.13
.11 PLUS DRAFT ANGLE (OPT.)
6 PL.
.250-28 UNF-3B X 2 DIA LENGTH
HL INSERT PER MS33537
OR MS33537-REMOVE TANG
(DRILL DEPTH .75)
.26
.24
.345
.325
.385
.375
.845
.825
ANODIZE PER MIL-A-8625, TYPE II, CLASS 2
(COLOR BLUE FED-STD-595, NO. 25180)
PART NO. 500420-1
AL ALY PLATE
7075-T7351
QQ-A-250/12, CON T7351
APPLICATION
END BELL ASSY
(LEAD END)
E 70210 500420
SCALE FULL
500420

3-29/3-30

2



FABRICATION

STEP 1. ASSEMBLE MACHINED PARTS, FIND NO. 1, 2, 6, 7, 8 & 9 (OMIT CLAMPS) AS SHOWN.

STEP 2. SPRAY ENTIRE ASSY WITH FIND NO. 11, LET DRY & BUFF LIGHTLY.

STEP 3. DIP ASSEMBLY IN FIND NO. 10 TO OPTAIN BUILD-UP AS SHOWN.

STEP 4. AIR DRY FOR 48 HR. THEN STEP CURE STARTING AT 150°F IN INCREMENTS OF 50°F PER HR. TO 300°F. TOTAL CURING TIME 4 HR.

STEP 5. ASSEMBLE CLAMP FIND NO. 5 AS SHOWN.

STEP 6. REMOVE FIND NO. 9.

STEP 7. PRESSURIZE INTERIOR TO TBD PSI TO SEPARATE BORE SEAL AT BOND LINE. (SEE DEFLECTION PRESSURE SCHEDULE).

STEP 8. REMOVE PRESSURE.

PRESSURE PSID	δ IN
.88	0
1.76	0
4.41	.05
8.80	.10
32.7 (PROOF PRESS)	.10

NOTES: UNLESS OTHERWISE SPECIFIED

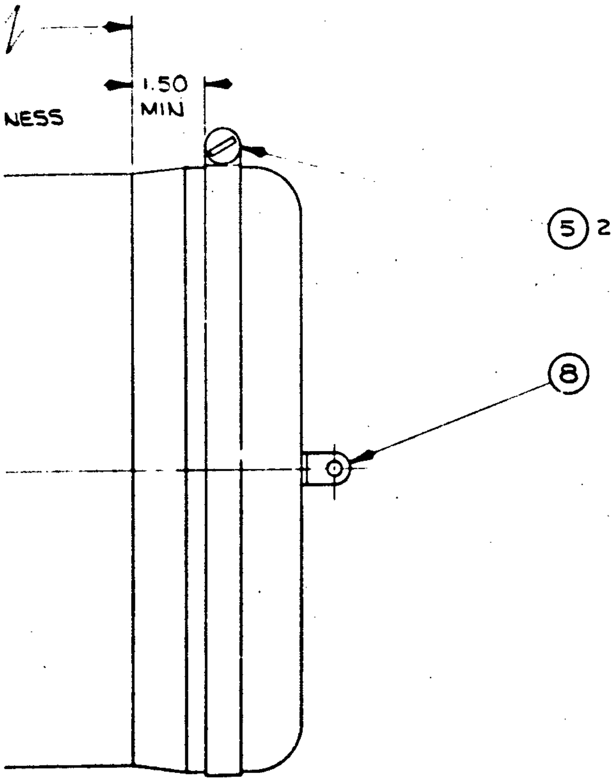
8 7 6 5 4

REV STATUS							
SHEET							

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

R



ESSURE PSID	δ IN
.88	0
1.76	0
1.41	.05
3.80	.10
2.7	.10
F PRESS)	

PART NO. SEE SEPARATE PARTS LIST

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER BC683 CL B STD INTERPRETATIONS PER PI66 IDENTIFICATION MARKING PER MC10

MATERIAL: SEE SEPERATE PARTS LIST

FINISH PROCESS

HEAT TREATMENT

CONTRACT NO

PREPARED BY NAKAMURA 810728

CHK 820107

DESIGN

VALUE ENGR

MATL

STRESS

APVD

DESIGN SUPERVISOR / PROJECT ENGINEER

GOVERNMENT APVD

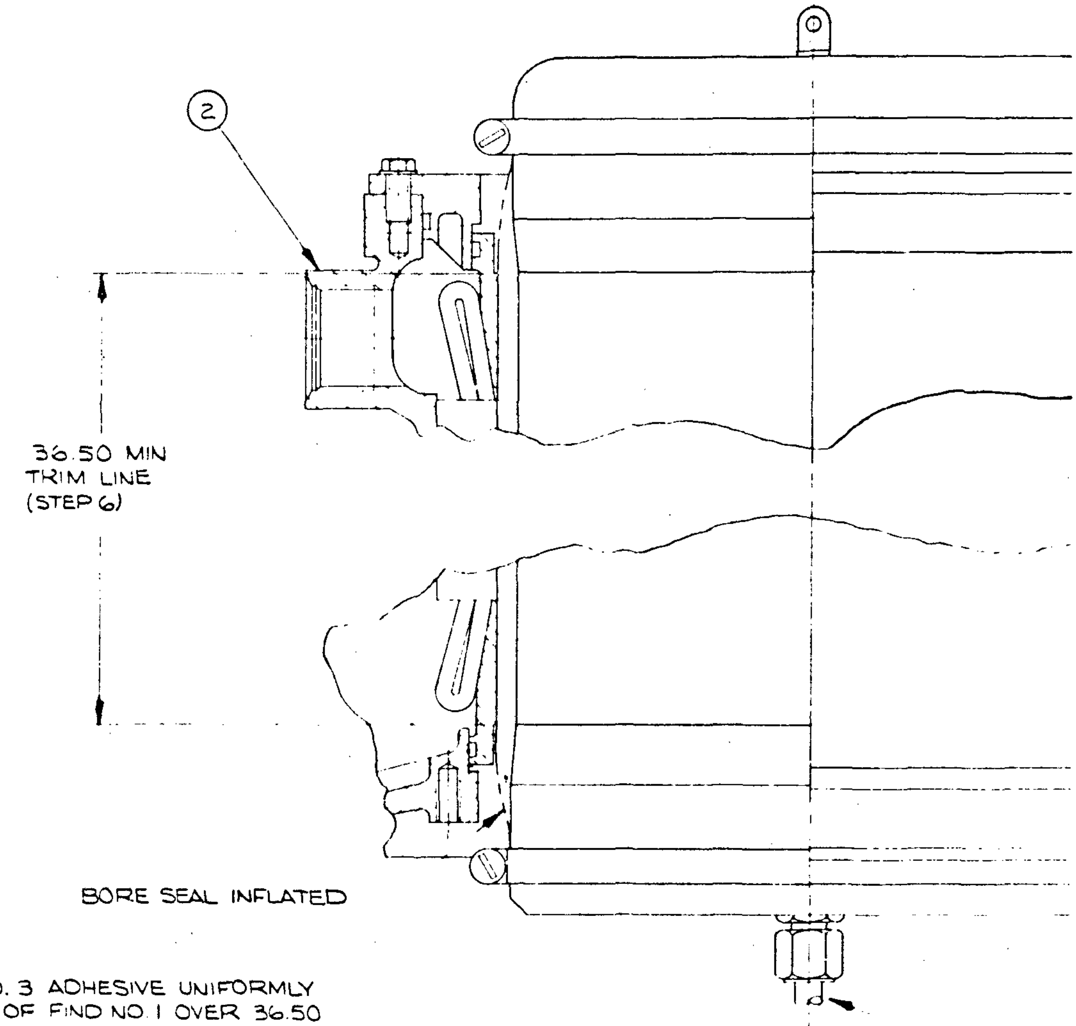
AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

BORE SEAL FABRICATION

SIZE	CODE IDENT NO	DWG NO
D	70210	500421

SCALE FULL — SHEET 1 OF 1

		518404
REQD	NEXT ASSY	USED ON
APPLICATION		



FABRICATION:

STEP 1- APPLY FIND NO. 3 ADHESIVE UNIFORMLY TO EXTERIOR OF FIND NO. 1 OVER 36.50 MIN LENGTH. PER RS 209-01

STEP 2- INFLATE BORE SEAL BY APPLYING 25-35 PSI

STEP 3- CURE PER RS 209 & MAINTAIN 25-35 PSI

STEP 4- REMOVE PRESSURE

STEP 5- REMOVE BORE SEAL TOOL.

STEP 6- TRIM AT POSITION INDICATED

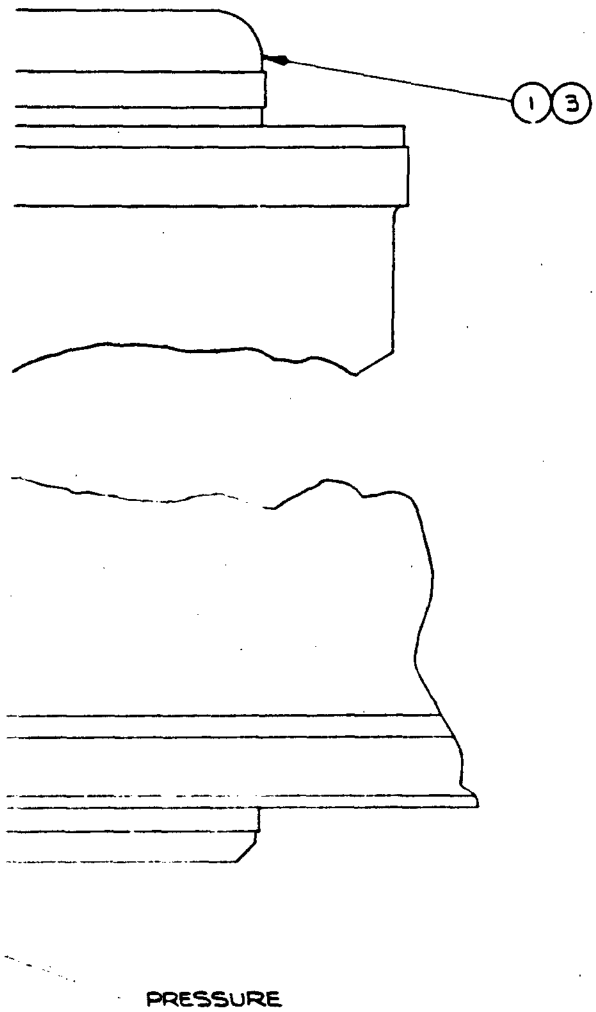
STEP 7- IDENTIFY ASSY AS

DWG NO 500422

ZONE	LTR	DESCRIPTION	DATE	APPROVED
REVISIONS				

R

REV STATUS							
SHEET							



PART NO. SEE SEPERATE PARTS LIST

UNLESS OTHERWISE SPECIFIED
BURR CONTROL PER SC663 - 1 B
STD INTERPRETATIONS PER PI98
IDENTIFICATION MARKING PER
MC16

MATERIAL

FINISH PROCESS

HEAT TREATMENT

REQD	NEXT ASSY	USED ON
APPLICATION		

CONTRACT NO

PREPARED BY 810730

CHK 820101

DESIGN

VALUE ENGR

MATL

STRESS

APPROVAL

DESIGN SUPERVISOR

PROJECT ENGINEER

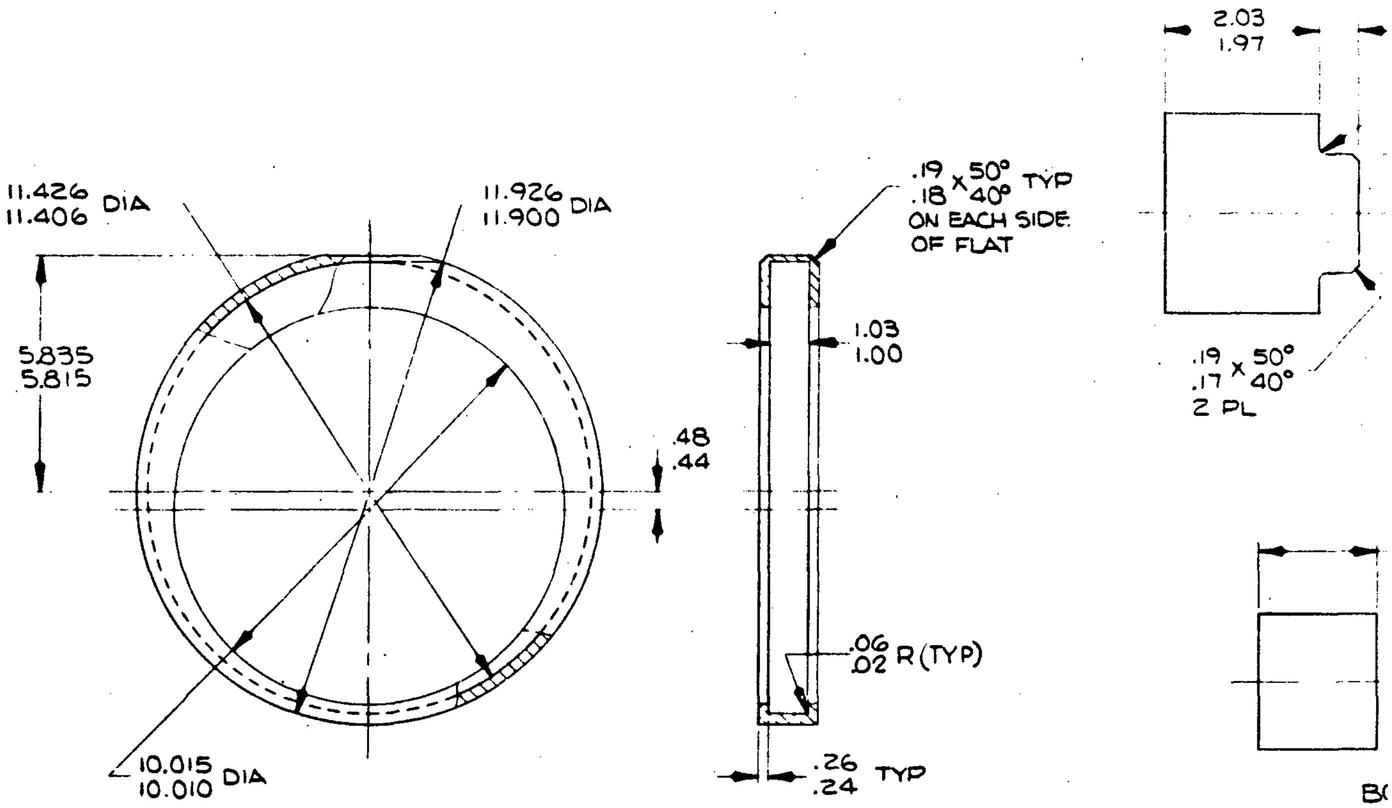
GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

BORE SEAL
ASSY

SIZE	CODE IDENT NO	DWG NO
D	70210	500422

SCALE FULL SHEET 1 OF 1



ANNULUS -1
SCALE = 1/2

1. AL ALY 6061-T6 PLATE
QQ-A-250/11 COND T651 OR
AL ALY 6061-T6 BAR
QQ-A-225/8 COND T651

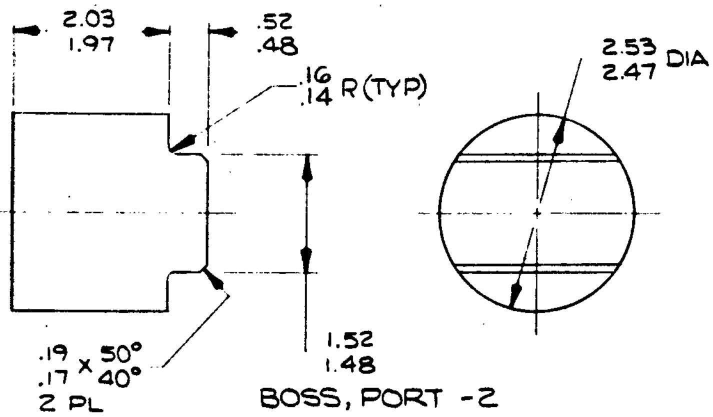
NOTES: UNLESS OTHERWISE SPECIFIED

500425

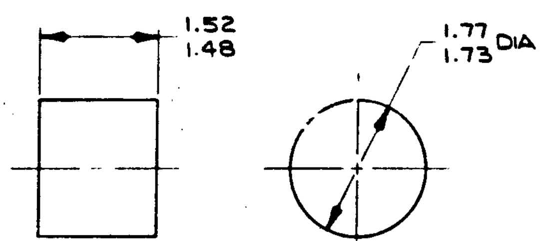
REV STATUS							
SHEET							

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED



BOSS, PORT -2



BOSS, PORT -3

PART NO. 500425-1,-2,& -3

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653
STD INTERPRETATIONS PER PIS
IDENTIFICATION MARKING PER MC16

MATERIAL
⚠ 1.

FINISH PROCESS

HEAT TREATMENT

CONTRACT NO

PREPARED BY NAKAMURA 811008

CHK

DESIGN

VALUE ENGR

MATL

STRESS

APVD

DESIGN SUPERVISOR

PROJECT ENGINEER

GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

DETAILS, ANNULUS

SIZE	CODE IDENT NO	DWG NO
D	70210	500425

SCALE FULL | SHEET | OF

REQD	NEXT ASSY	USED ON
1 (-3)	500411-1	518404-1
1 (-3)	500410-1	518404-1
1 (-2)	500409-1	518404-1
1 (-1)	500409-1	518404-1

APPLICATION

ECIFIED

D

C

B

A

4 3 2 1

3-35/3-36

2

DWG NO 5004

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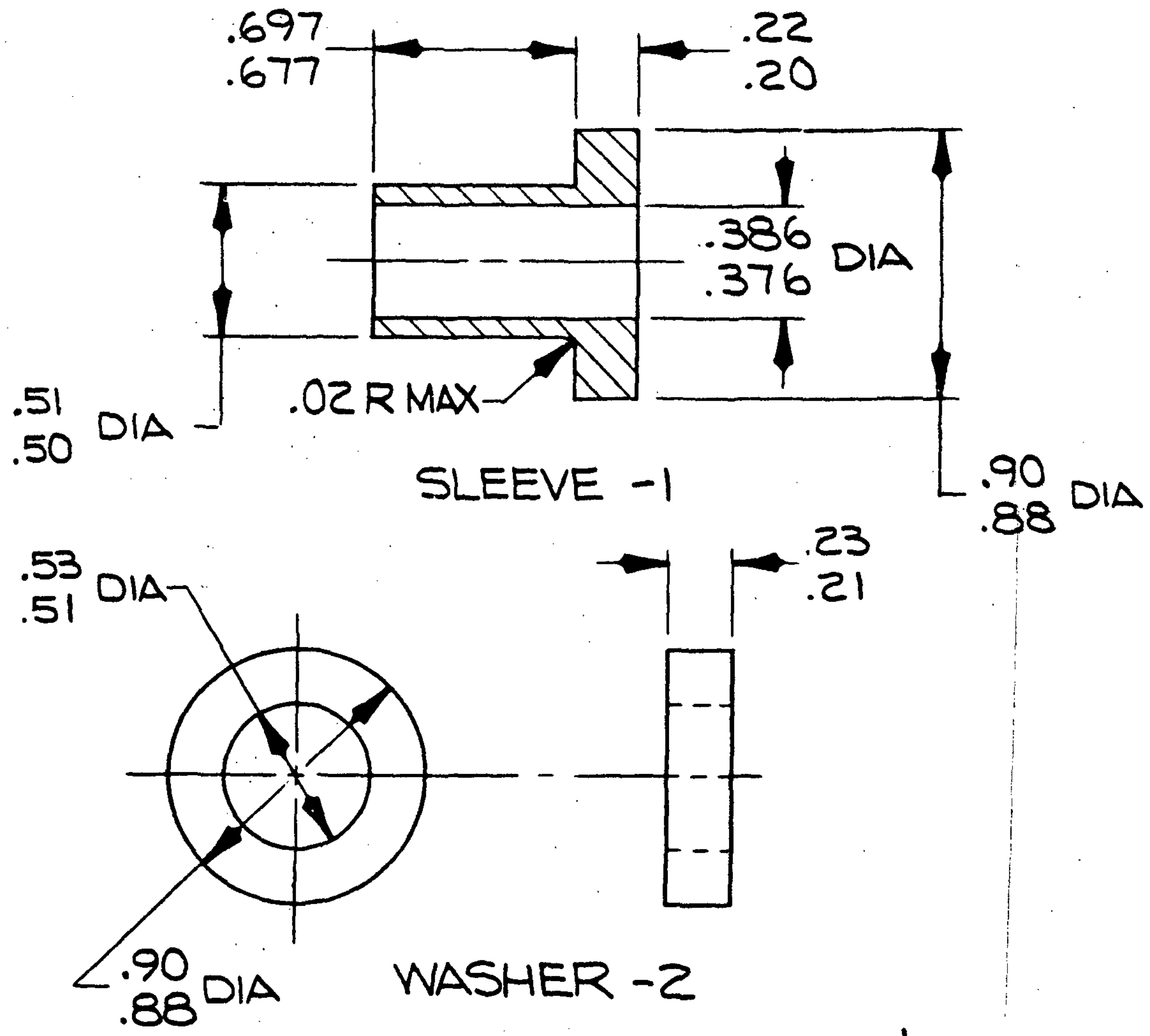


PART NO 500426-1 & -2

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CLB
STD INTERPRETATIONS PER P185
IDENTIFICATION MARKING PER
MC16

42(-2)	500430-1	518404-1
42(-1)	500430-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

MATERIAL
NEMA GRADE G11
1.00 DIA BAR

HEAT TREATMENT

FINISH PROCESS
1

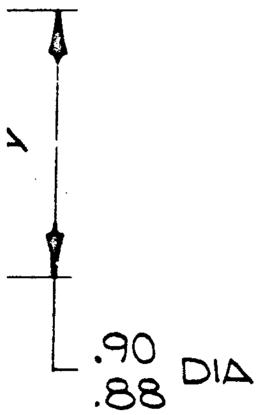
CONTR
PREPAR
CHK
VALUE
MATL
STRESS
DESIGN
PROJEC
GOVER

FORM 1186

DWG NO 500426 SH A

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
A	SEE EO	820109	W.H. House

R
R



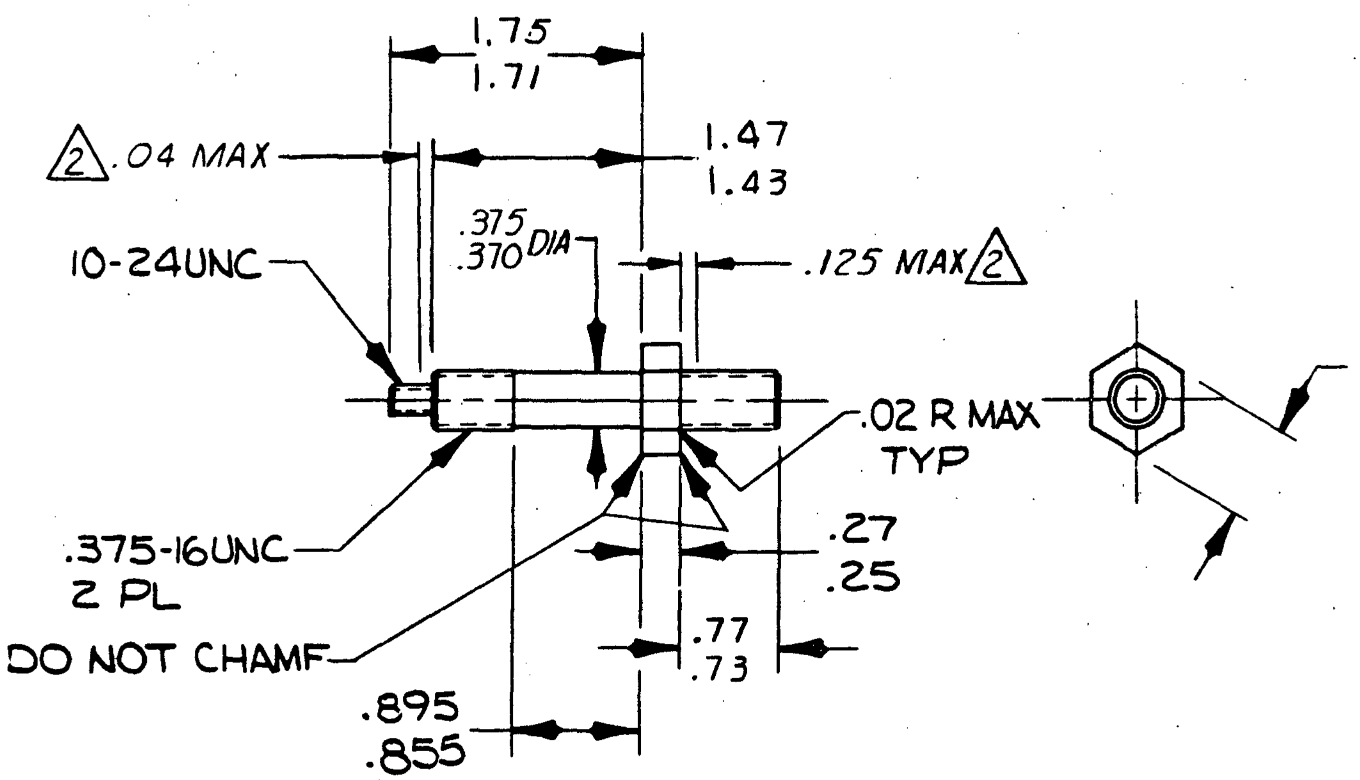
NOTES

⚠1 SEALING COAT PER RS13 ALL OVER
APPLY 117-011-9001 USING 117-016-9001,
ADD ONE DROP OF 3M FC430 WETTING
AGENT TO EACH 100 GRAMS.
AFTER DIPPING .001 MAX BUILD UP, IF TOO
MUCH BUILD UP CONSULT ENGINEERING.

MATERIAL NEMA GRADE G11 1.00 DIA BAR	CONTR NO	AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
	PREPARED BY NAKAMURA 811007		
	CHK [signature] 811009	INSULATOR, TERMINAL	
	VALUE ENGR		
	MATL [signature] 811102		
HEAT TREATMENT	STRESS		
	DESIGN SUPERVISOR 11-2-81 [signature]	SIZE B	CODE IDENT NO 70210 / DWG NO 500426
FINISH PROCESS ⚠1	PROJECT ENGINEER 81-11-02 [signature]	SCALE 2/1	SHEET 1 OF 1
	GOVERNMENT APVD		

3-37/3-38 2

DWG NO 50042



PART NO 500427-1

2 INCOMPLETED THREAD

1. .625 HEX BAR
ZIRCONIUM COPPER
CDA-150 (HARD)

NOTES: UNLESS OTHERWISE
SPECIFIED

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CL B
STD INTERPRETATIONS PER PIB5
IDENTIFICATION MARKING PER
MC18

43(-1)	500430-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

MATERIAL
1.

HEAT TREATMENT

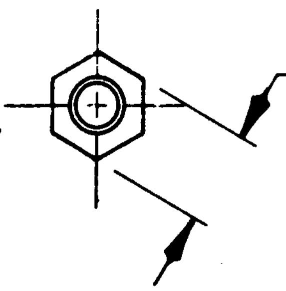
FINISH PROCESS

CONTR NO
PREPARED B
CHK
VALUE ENGR
MATL
STRESS
DESIGN SUPE
PROJECT ENG
GOVERNMEN

FORM 1195

DWG NO 500427 SH A

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
A	SEE E.O	820109	W.H. Ham



·7 - 1

ECIFIED:
C653 CLB
S PER P185
KING PER

18404-1
USED ON

MATERIAL
1.

HEAT TREATMENT

FINISH PROCESS

CONTR NO
PREPARED BY NAKAMURA 811008
CHK 811007
VALUE ENGR
MATL
STRESS
DESIGN SUPERVISOR 11-2-81
PROJECT ENGINEER 81-11-02
GOVERNMENT APVD

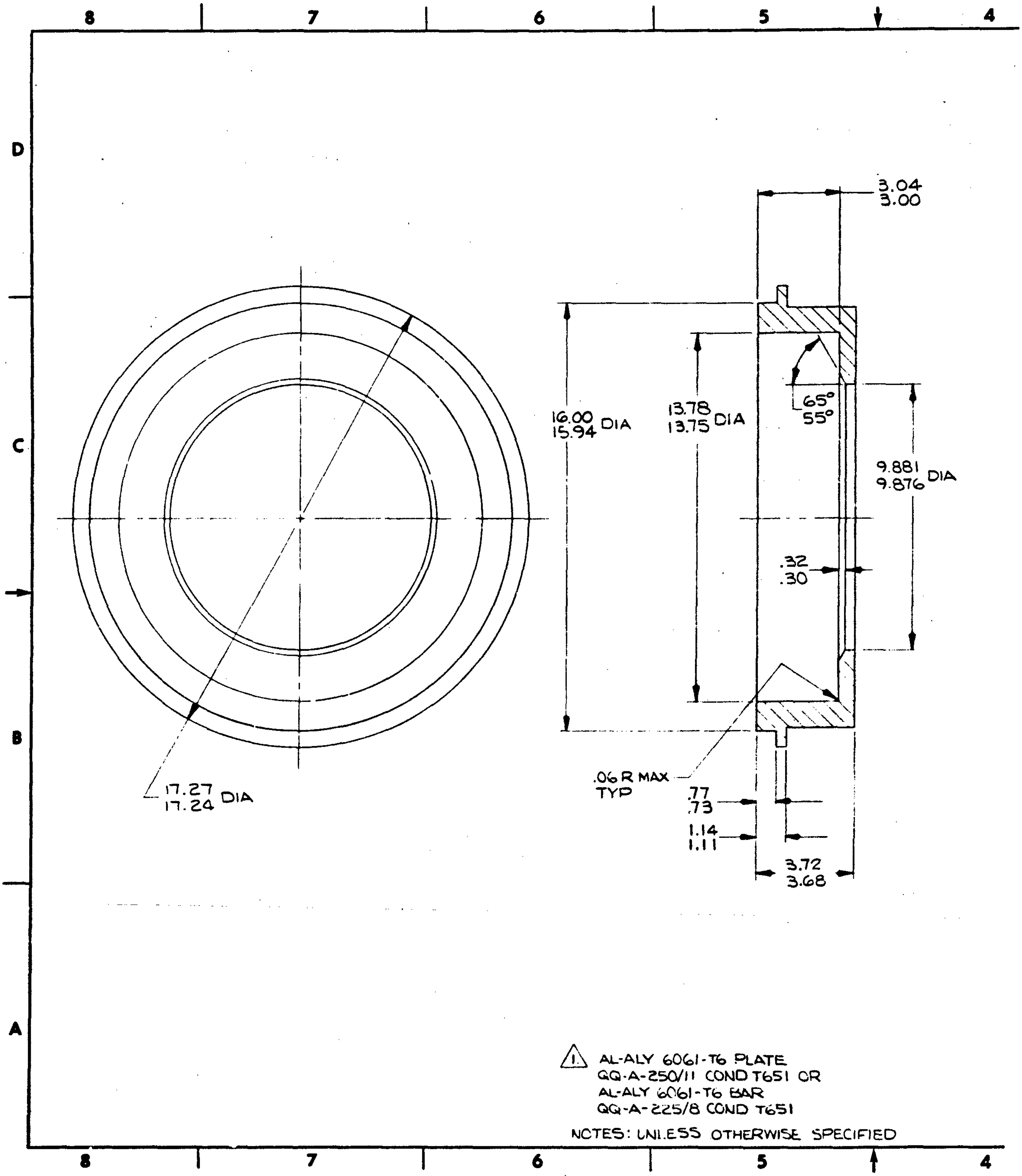
AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

TERMINAL, ELECT.

SIZE B | CODE IDENT NO 70210 | DWG NO 500427

SCALE FULL | SHEET 1 OF 1

3-39/3-40 2



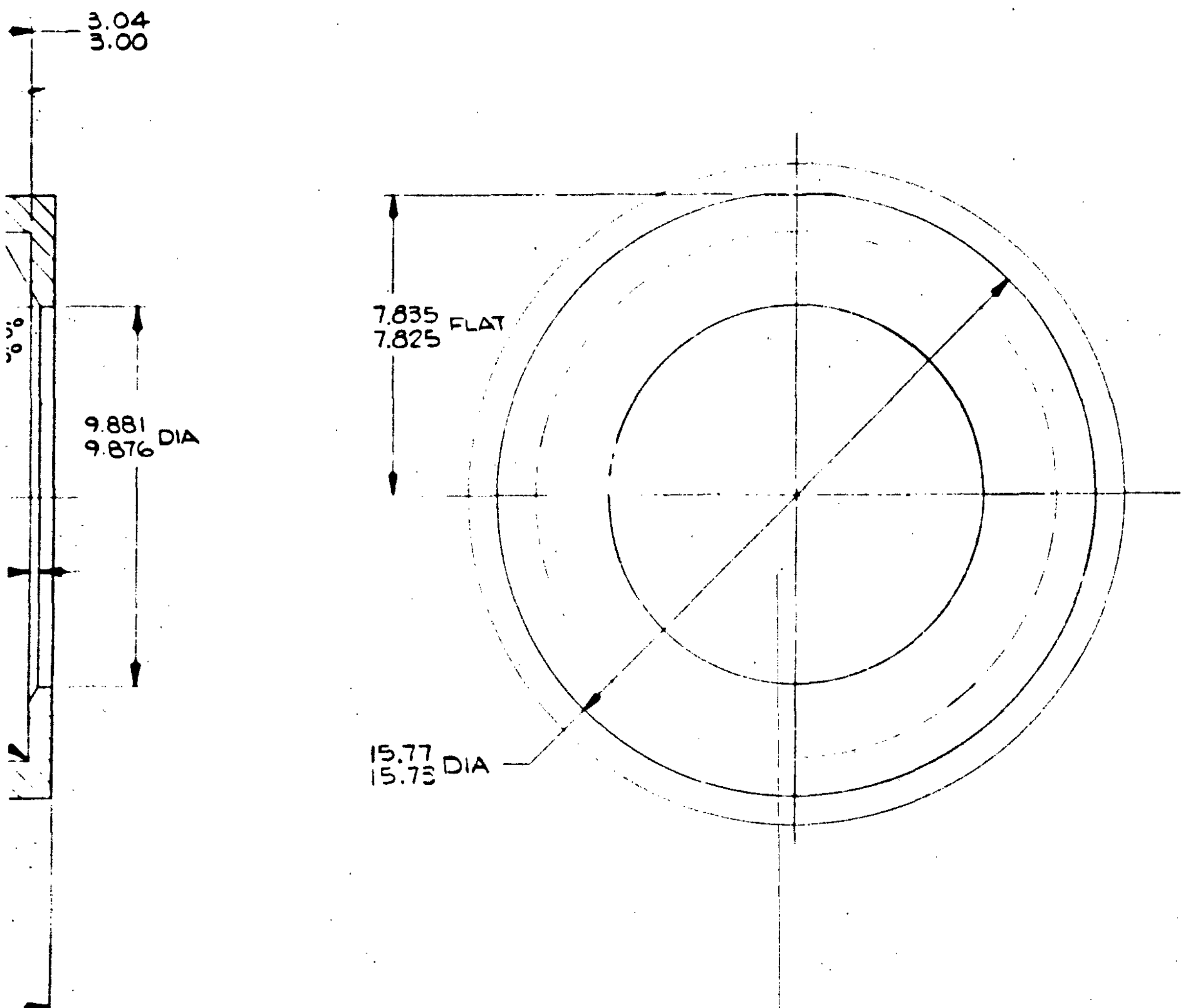
1. AL-ALY 6061-T6 PLATE QQ-A-250/11 COND T651 OR AL-ALY 6061-T6 BAR QQ-A-225/8 COND T651

NOTES: UNLESS OTHERWISE SPECIFIED

	A	SEE ENGINEERING ORDER	1-18-82	

REV STATUS

SHEET



PECIFIED

PART NO 500428-1

UNLESS OTHERWISE SPECIFIED
BURR CONTROL PER SC663
STD INTERPRETATIONS PER PI65
IDENTIFICATION MARKING PER
MC16

MATERIAL

FINISH PROCESS

HEAT TREATMENT

CONTRACT NO

PREPARED BY NAKAMURA 811009

DESIGN

VALUE ENGR

MATL

STRESS

APVD

DESIGN SUPERVISOR

PROJECT ENGINEER

GOVERNMENT APVD

1 (-1)		518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

PLATE, FLANGED, TERMINAL

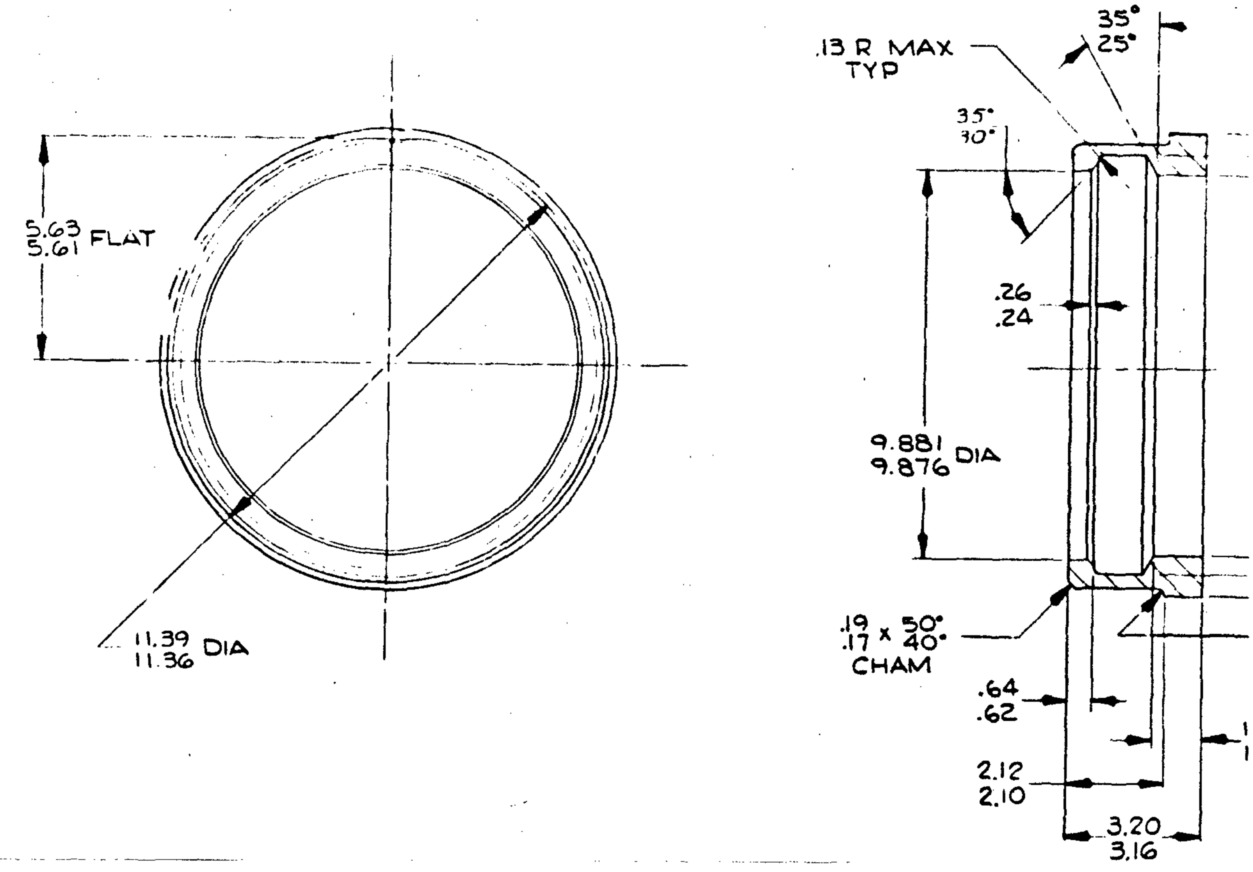
SIZE	CODE IDENT NO	DWG NO
D	70210	500428

SCALE 1/2 SHEET 1 OF 1

4 3 2 1

D C B A

2 3-41/3-42

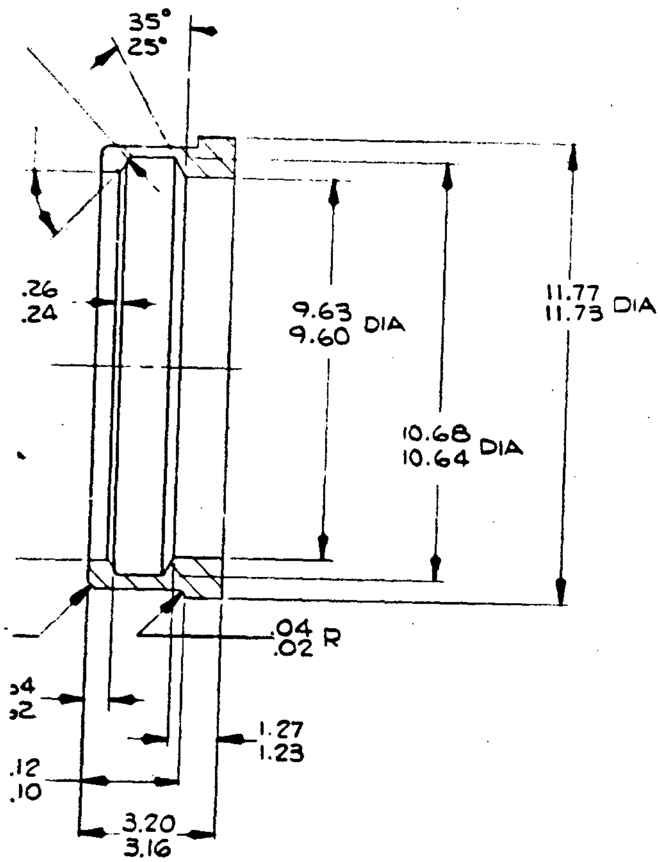


⚠1 AL-ALY 6061-T6 PLATE
QQ-A-250/11 COND T651 OR
AL-ALY 6061-T6 BAR
QQ-A-225/8 COND T651

NOTES: UNLESS OTHERWISE SPECIFIED

REV STATUS							
SHEET							

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE ENGINEERING ORDER		



E
.51 OR
51
SE SPECIFIED

PART NO. 500429-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC053
STD INTERPRETATIONS PER PIRS
IDENTIFICATION MARKING PER MC10

MATERIAL

FINISH PROCESS

HEAT TREATMENT

1(-1)	500410-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

CONTRACT NO

PREPARED BY NAKAMURA 8/10/62

CHK

DESIGN

VALUE ENGR

MATL

STRESS

APVD

DESIGN SUPERVISOR

PROJECT ENGINEER

GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

SUPPORT, HOUSING

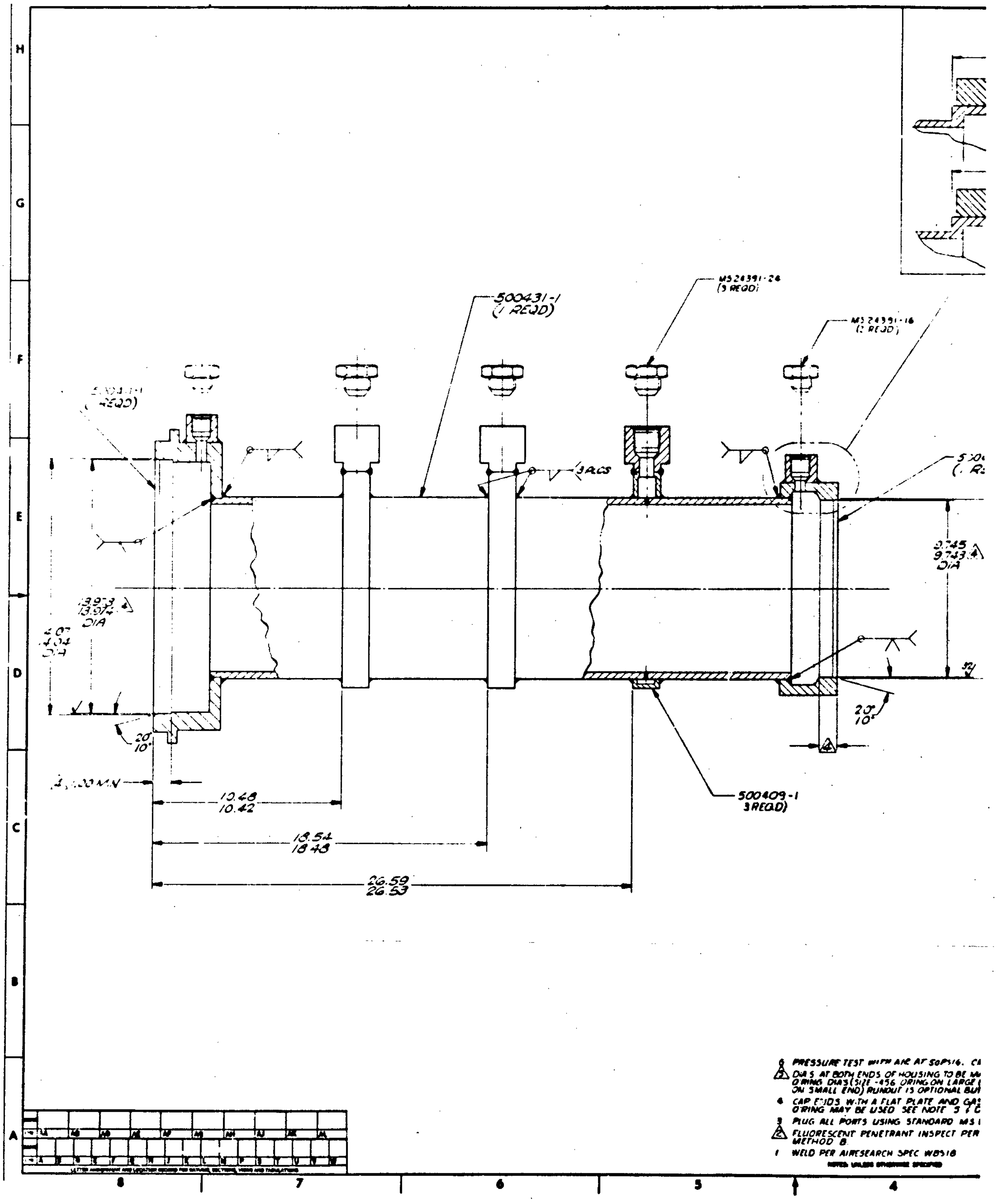
SIZE	CODE IDENT NO	DWG NO
D	70210	500429

SCALE 1/2 SHEET 1 OF 1

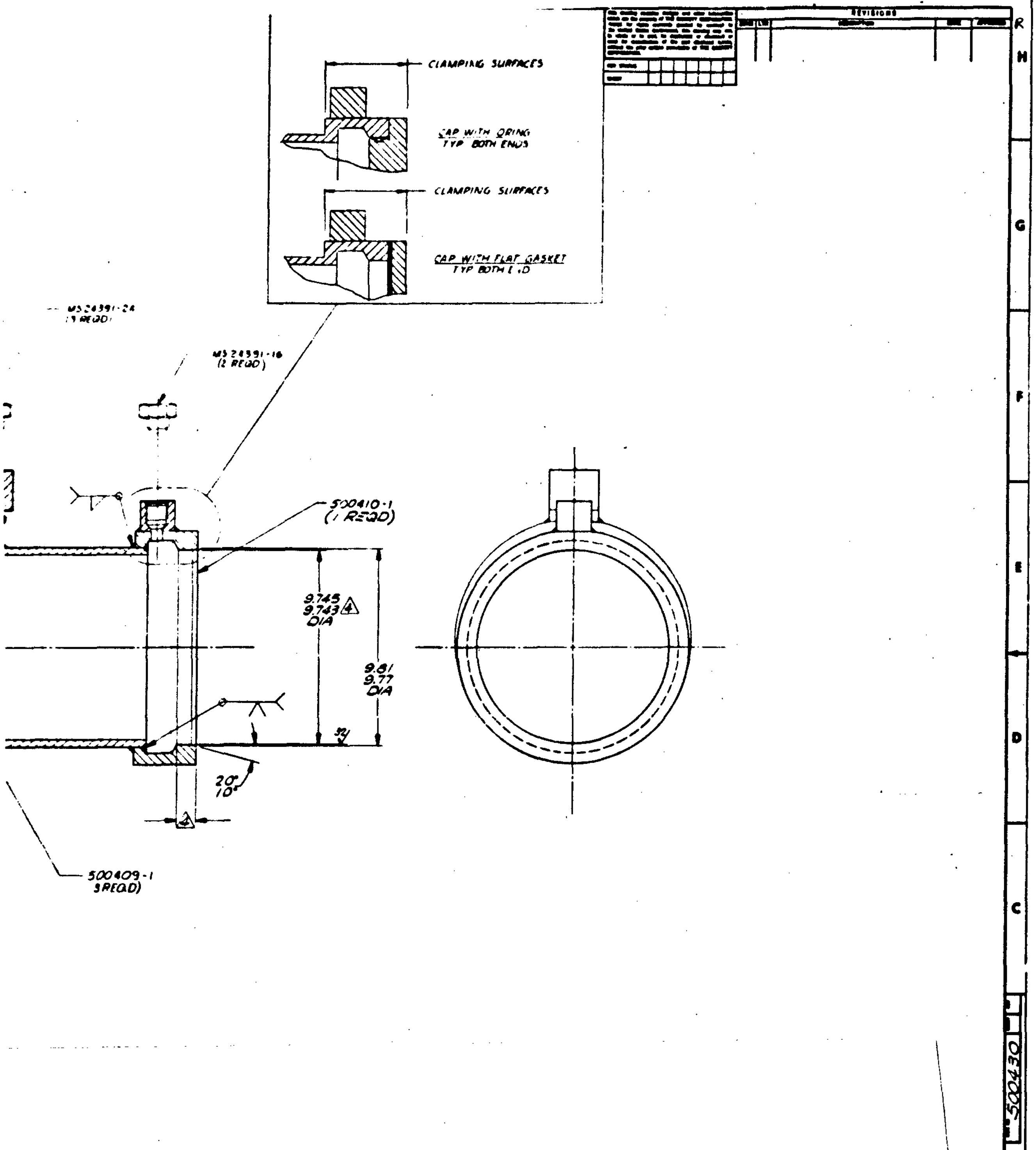
4 3 2 1

3-43/3-44

2



MS24391-24
(5 REQD)
500431-1
(1 REQD)
MS24391-16
(2 REQD)
3 PLCS
9.745
9.743
DIA
13.974
DIA
20°
10°
10.48
10.42
18.54
18.48
26.59
26.53
500409-1
3 REQD)
6 PRESSURE TEST WITH AIR AT 50PSIG.
5 DIA S AT BOTH ENDS OF HOUSING TO BE
O'RING DIAS (SIZE -456 ORING ON LARGE
ON SMALL END) RUNOUT IS OPTIONAL
4 CAP ENDS WITH A FLAT PLATE AND
O'RING MAY BE USED SEE NOTE 5
3 PLUG ALL PORTS USING STANDARD MS
2 FLUORESCENT PENETRANT INSPECT PER
METHOD B.
1 WELD PER AIRESEARCH SPEC WB518



6 PRESSURE TEST WITH AIR AT 50PSIG. CHECK WITH LEAK-TEK

5 DIA'S AT BOTH ENDS OF HOUSING TO BE MACHINED TO PROVIDE O RING DIAS (SIZE -456 ORING ON LARGE END & SIZE -272 ORING ON SMALL END) RUNOUT IS OPTIONAL BUT CLEANUP MUST BE 100%

4 CAP ENDS WITH A FLAT PLATE AND GASKET OR PLUGS WITH O RING MAY BE USED SEE NOTE 3 & DETAIL SHOWN

3 PLUG ALL PORTS USING STANDARD MS PLUGS AS SHOWN

2 FLUORESCENT PENETRANT INSPECT PER MIL-I-6860, TYPE I, METHOD B

1 WELD PER AIRESEARCH SPEC WB518

NOTES: UNLESS OTHERWISE SPECIFIED

-1	500402-1	518404-1
	NEXT ASSY	USED ON
APPLICATION		

PART NO. 500430-1

MIL-H-6088
COND. T6

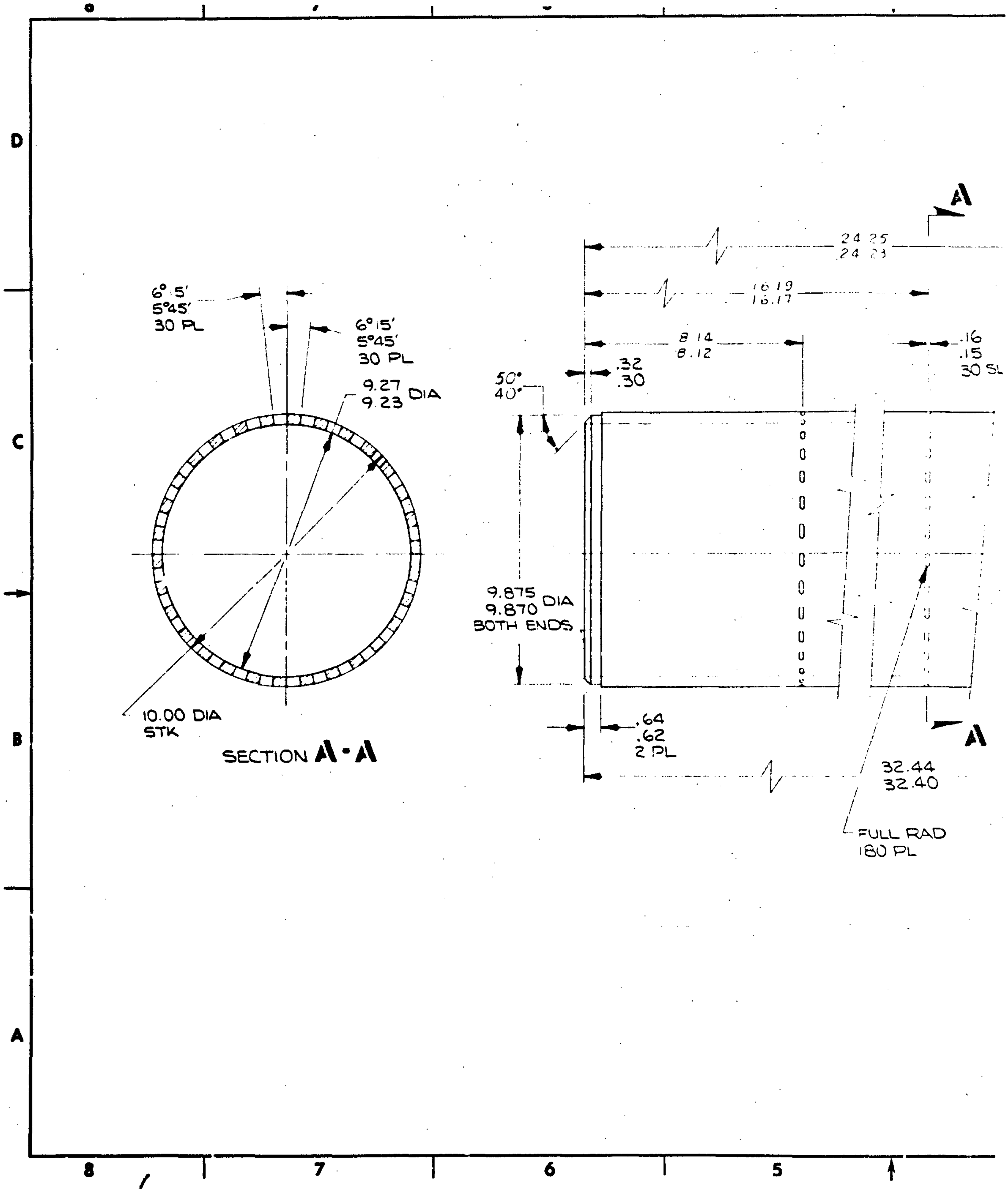
HOUSING, STATOR, FABRICATED

E 70210 500430

SCALE 1/2 SHEET 1 OF 1

3-45/3-46

2



D
C
B
A
8
7
6
5
A
24.25
24.23
16.19
16.17
8.14
8.12
.16
.15
30 SL
6°15'
5°45'
30 PL
6°15'
5°45'
30 PL
9.27
9.23 DIA
50°
40°
.32
.30
9.875
9.870 DIA
BOTH ENDS
.64
.62
2 PL
32.44
32.40
FULL RAD
180 PL
10.00 DIA
STK
SECTION A-A

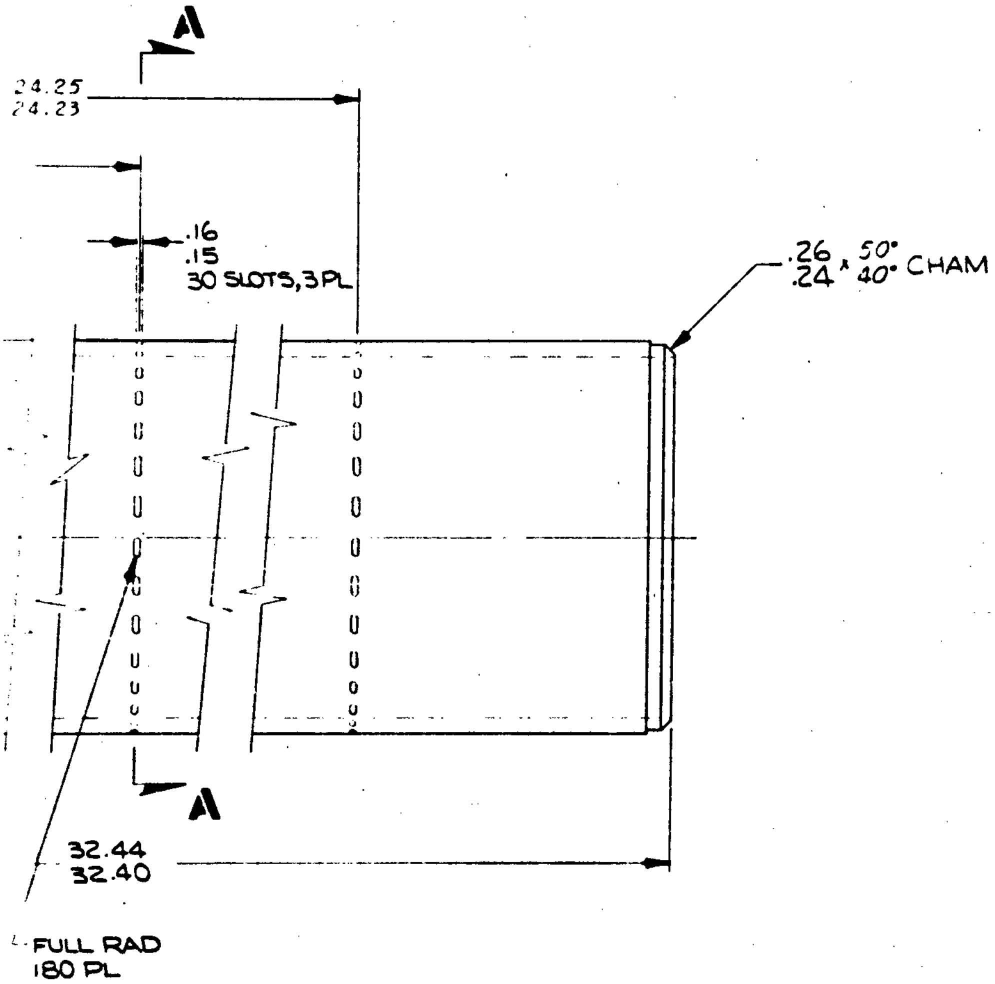
REV STATUS							
SHEET							

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

+R

D



C

B

A

PART NO. 500431-1

UNLESS OTHERWISE SPECIFIED
BURR CONTROL PER SC852
STD INTERPRETATIONS PER P98
IDENTIFICATION MARKING PER MC18

MATERIAL
AL-ALY TUBING
10.00 O.D. X .375 WALL
6061 T6511

FINISH PROCESS

HEAT TREATMENT

1(-1)	500430-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

CONTRACT NO

PREPARED BY NAKAMURA 81.10.09
CHK 81.10.12
DESIGN
VALUE ENGR
MATL
STRESS
APPVD
DESIGN SUPERVISOR
PROJECT ENGINEER
GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

TUBE, HOUSING

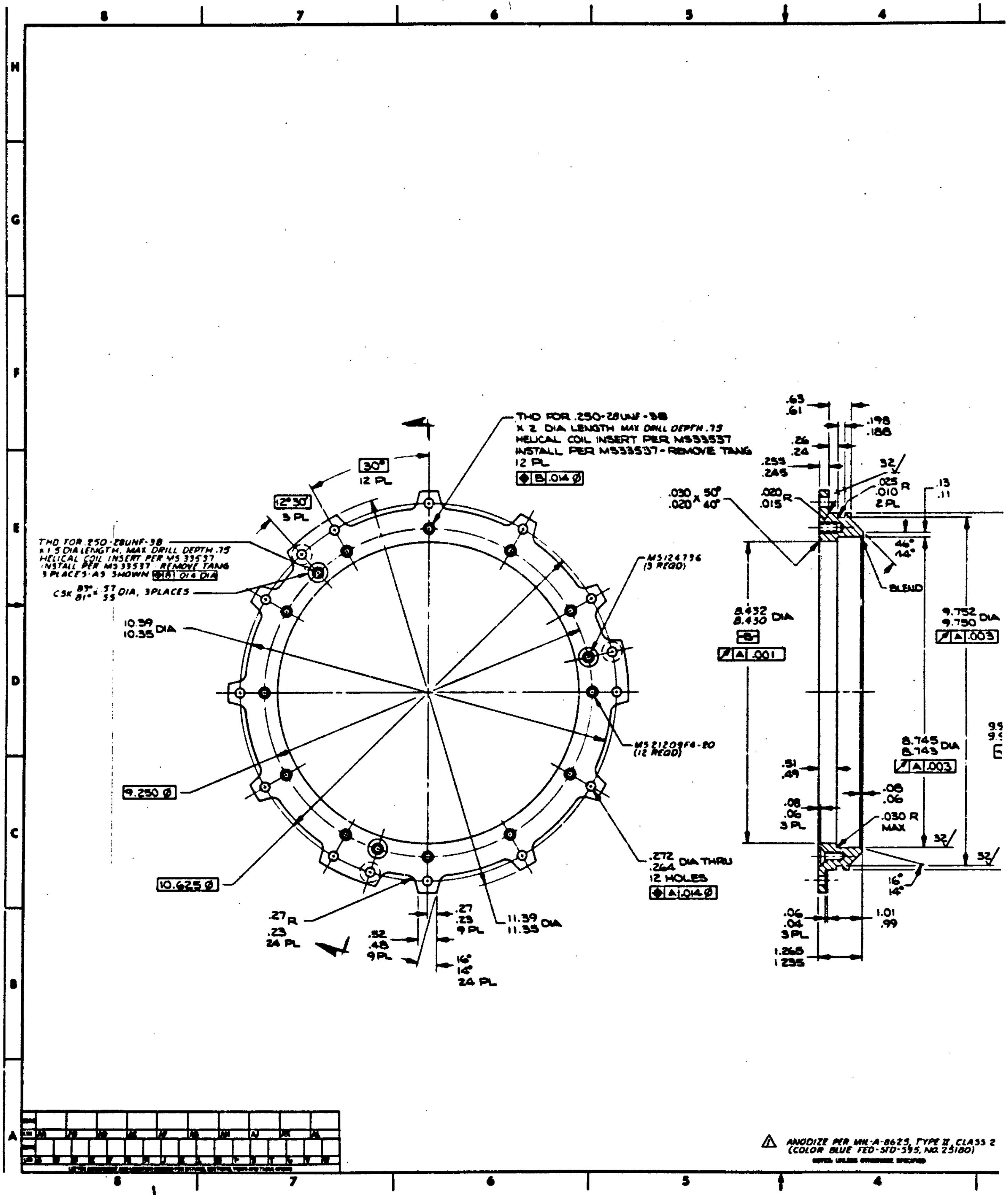
SIZE	CODE IDENT NO	DWG NO
D	70210	500431

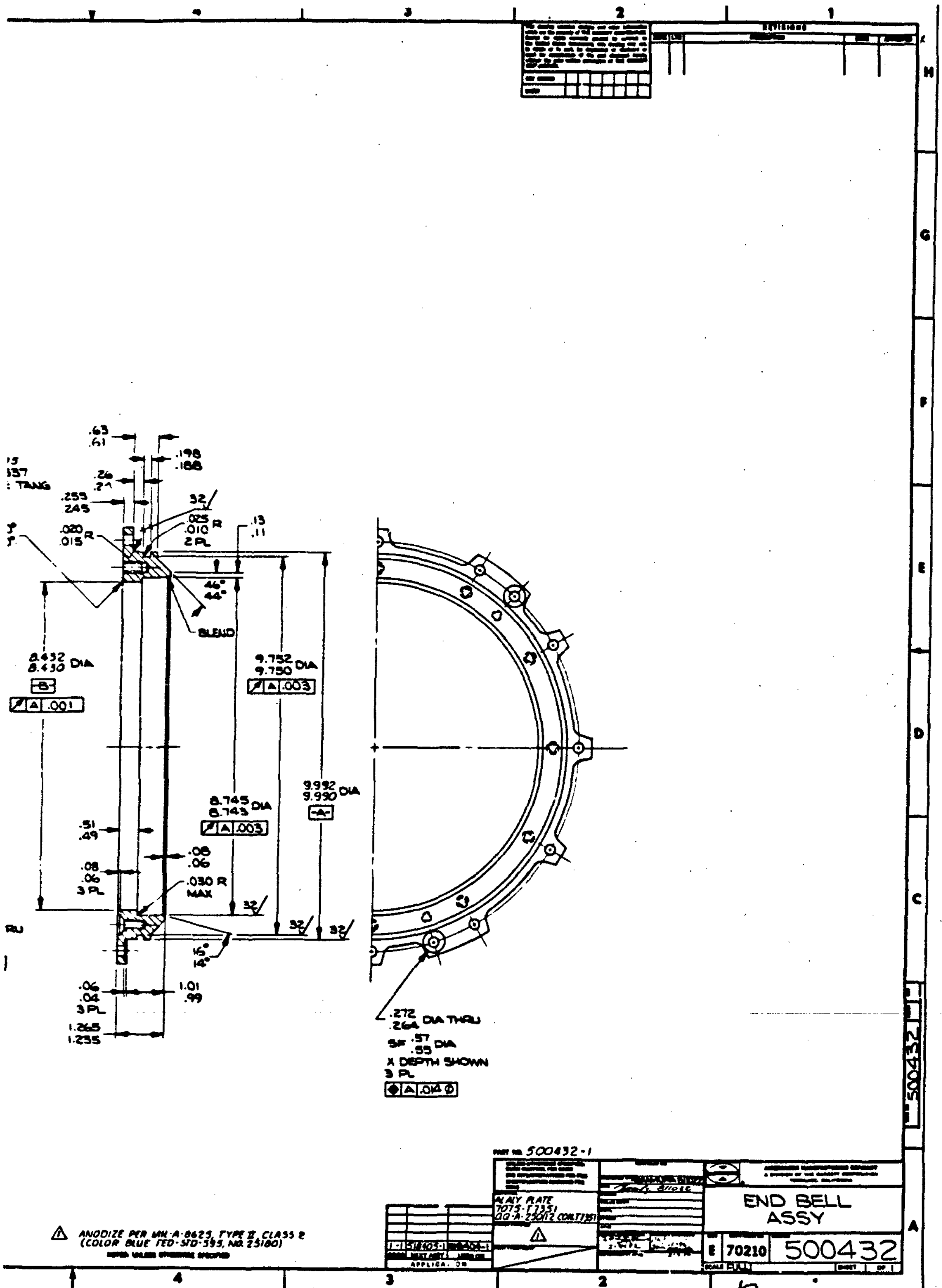
SCALE 1/2 SHEET 1 OF 1

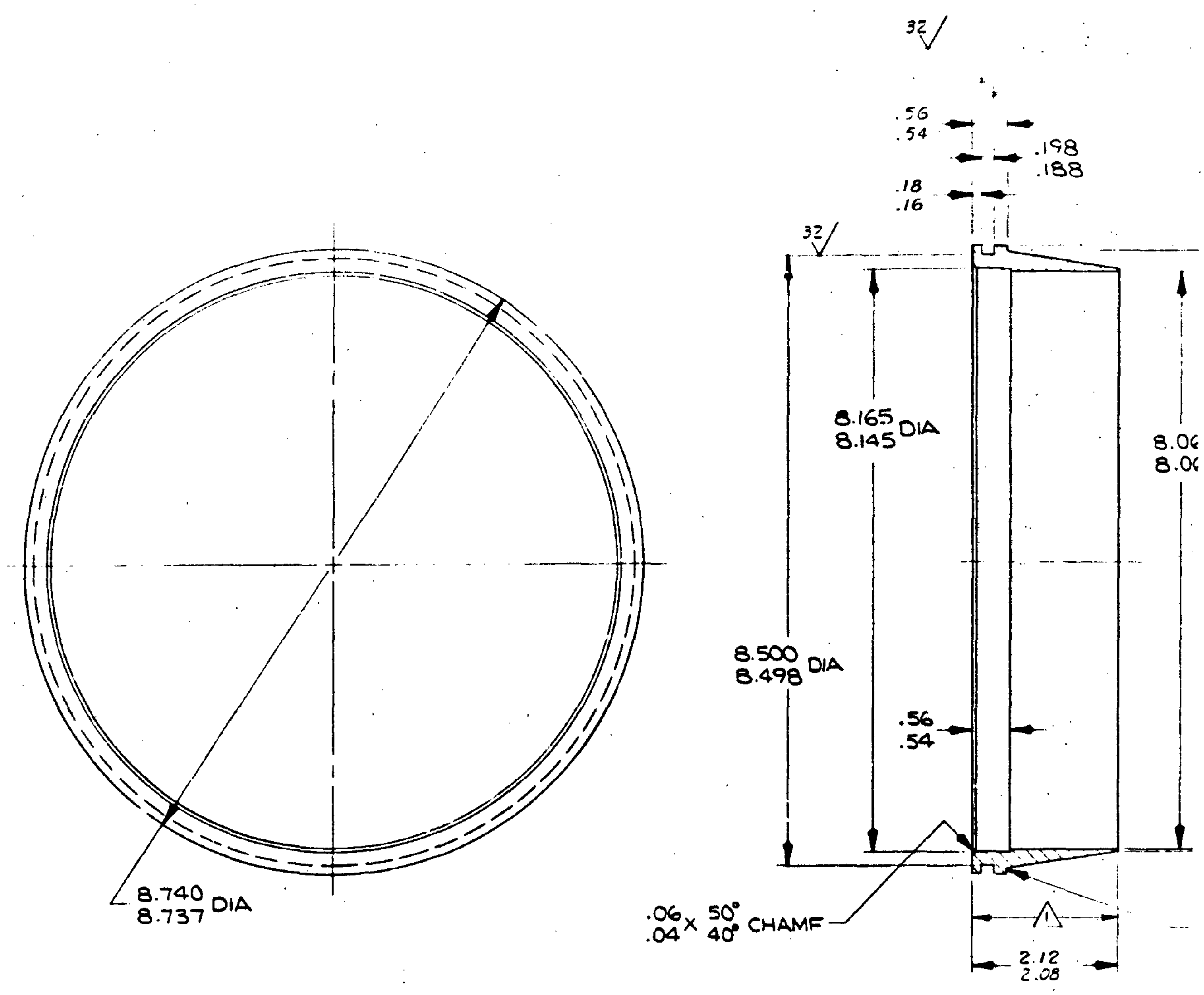
4 3 2 1

3-47/3-48

2


THD FOR .250-28UNF-3B X 2 DIA LENGTH MAX DRILL DEPTH .75 HELICAL COIL INSERT PER MS33537 INSTALL PER MS33537 - REMOVE TANG 12 PL
B .014 Ø
30° 12 PL
12°30' 3 PL
THD FOR .250-28UNF-3B X 1.5 DIA LENGTH, MAX DRILL DEPTH .75 HELICAL COIL INSERT PER MS33537 INSTALL PER MS33537 - REMOVE TANG 3 PLACES AS SHOWN B .014 DIA
CSK 89° 81° X .57 .55 DIA, 3 PLACES
10.39 10.35 DIA
MS124756 (3 REQD)
MS21209F4-20 (12 REQD)
9.250 Ø
10.625 Ø
.272 .264 DIA THRU 12 HOLES
A .014 Ø
.27 .23 R 24 PL
.52 .48 9 PL
.27 .23 9 PL
16° 14° 24 PL
11.39 11.35 DIA
.63 .61
.198 .188
.26 .24
.255 .245
.030 .020 X 50° 40°
.020 .015 R
32
.025 .010 R 2 PL
.13 .11
46° 44°
BLEND
8.432 8.430 DIA
B
A .001
9.752 9.750 DIA
A .003
8.745 8.743 DIA
A .003
.51 .49
.08 .06
.08 .06 3 PL
.030 R MAX
32
32
16° 14°
.06 .04 3 PL
1.01 .99
1.265 1.235
ANODIZE PER MIL-A-8625, TYPE II, CLASS 2 (COLOR BLUE FED-STD-595, NO. 25180)
NOTES: UNLESS OTHERWISE SPECIFIED


END BELL
ASSY
E
70210
500432
PART NO. 500432-1
AL ALY PLATE
7075-T7351
QQ-A-250/12 CONT7351
SCALE FULL
ANODIZE PER MIL-A-8625, TYPE II, CLASS 2
(COLOR BLUE FED-STD-595, NO. 25180)
NOTES: UNLESS OTHERWISE SPECIFIED
BLEND
8.432
8.430 DIA
-B-
.001
9.752
9.750 DIA
.003
8.745
8.743 DIA
.003
9.992
9.990 DIA
-A-
.030 R
MAX
.272
.264 DIA THRU
SF .57
.55 DIA
X DEPTH SHOWN
3 PL
.014
1.265
1.235
1.01
.99
APPLICATION



⚠1 SEALING COAT PER R513 IN AREA INDICATED, APPLY 117-011-9001 USING 117-016-9001, ADD ONE DROP OF 3M FC430 WETTING AGENT TO EACH 100 GRAMS, APPLY .001 THICK MAX. IF TO MUCH BUILD UP CONSULT ENGINEERING.

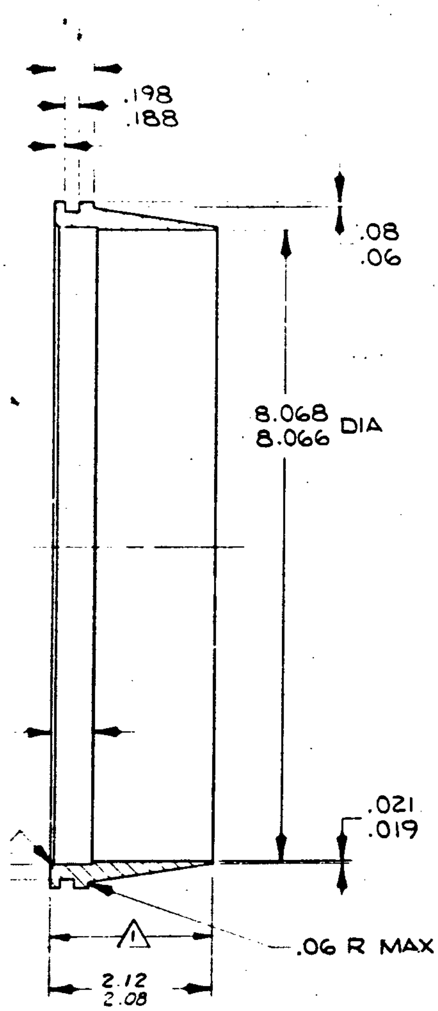
NOTES: UNLESS OTHERWISE SPECIFIED

REV STATUS							
SHEET							

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

D



C

B

A

CATED, APPLY 117-011-3001
OF 3M FC430 WETTING
001 THICK MAX.
IGINEERING.

PART NO. 500433

2(-1)	500400	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC663 CLB
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER MC16

MATERIAL
NEMA GRADE G11
EPOXY GLASS
LAMINATED

FINISH PROCESS

HEAT TREATMENT

CONTRACT NO

PREPARED BY NAKAMURA 811016
CHK 811019
DESIGN
VALUE ENGR
MATL
STRESS
APVD W. H. 82 104
DESIGN SUPERVISOR
PROJECT ENGINEER
GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

SUPPORT, *BORE SEAL*

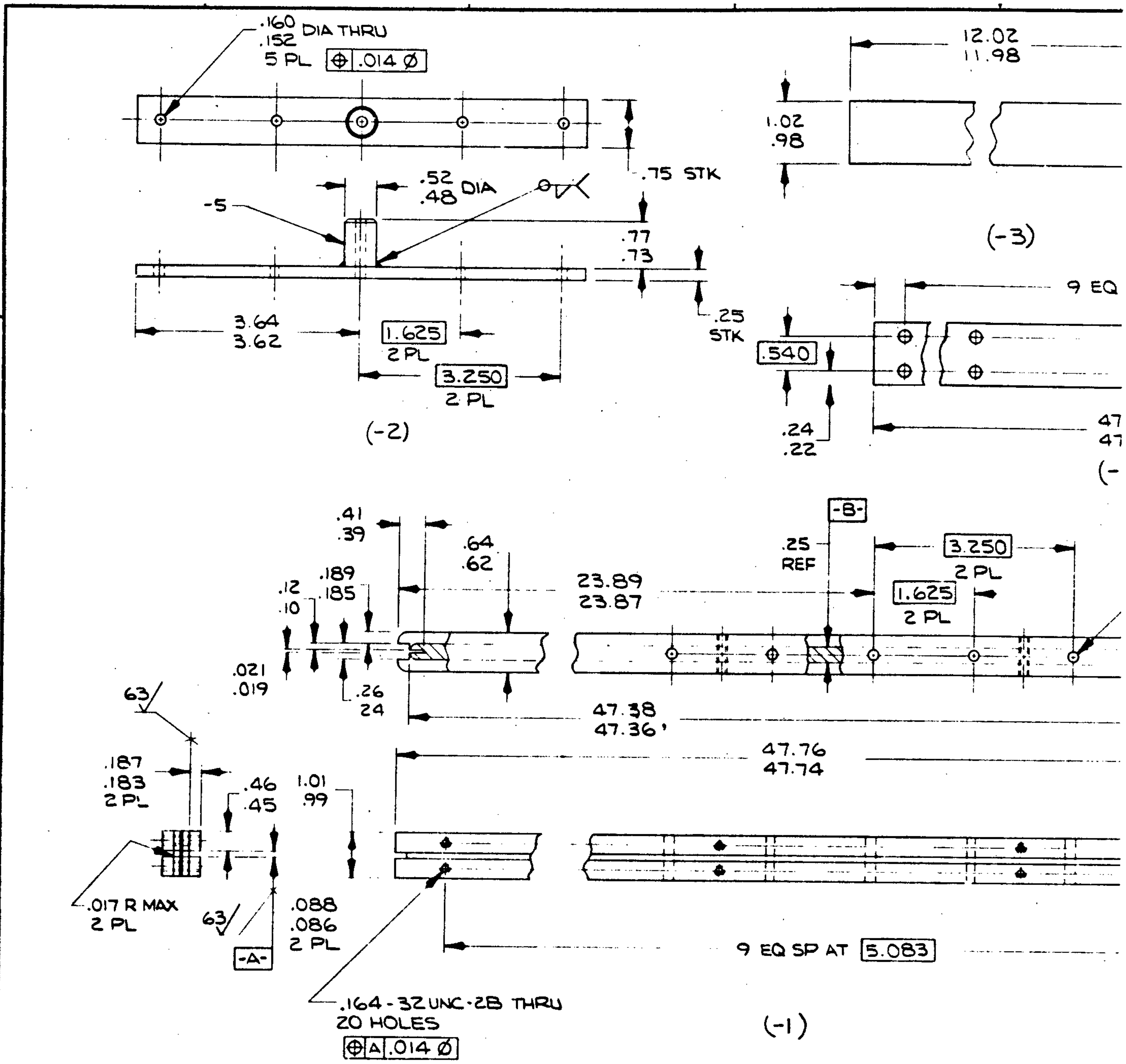
SIZE	CODE IDENT NO	DWG NO
D	70210	500433

SCALE FULL | SHEET 1 OF 1

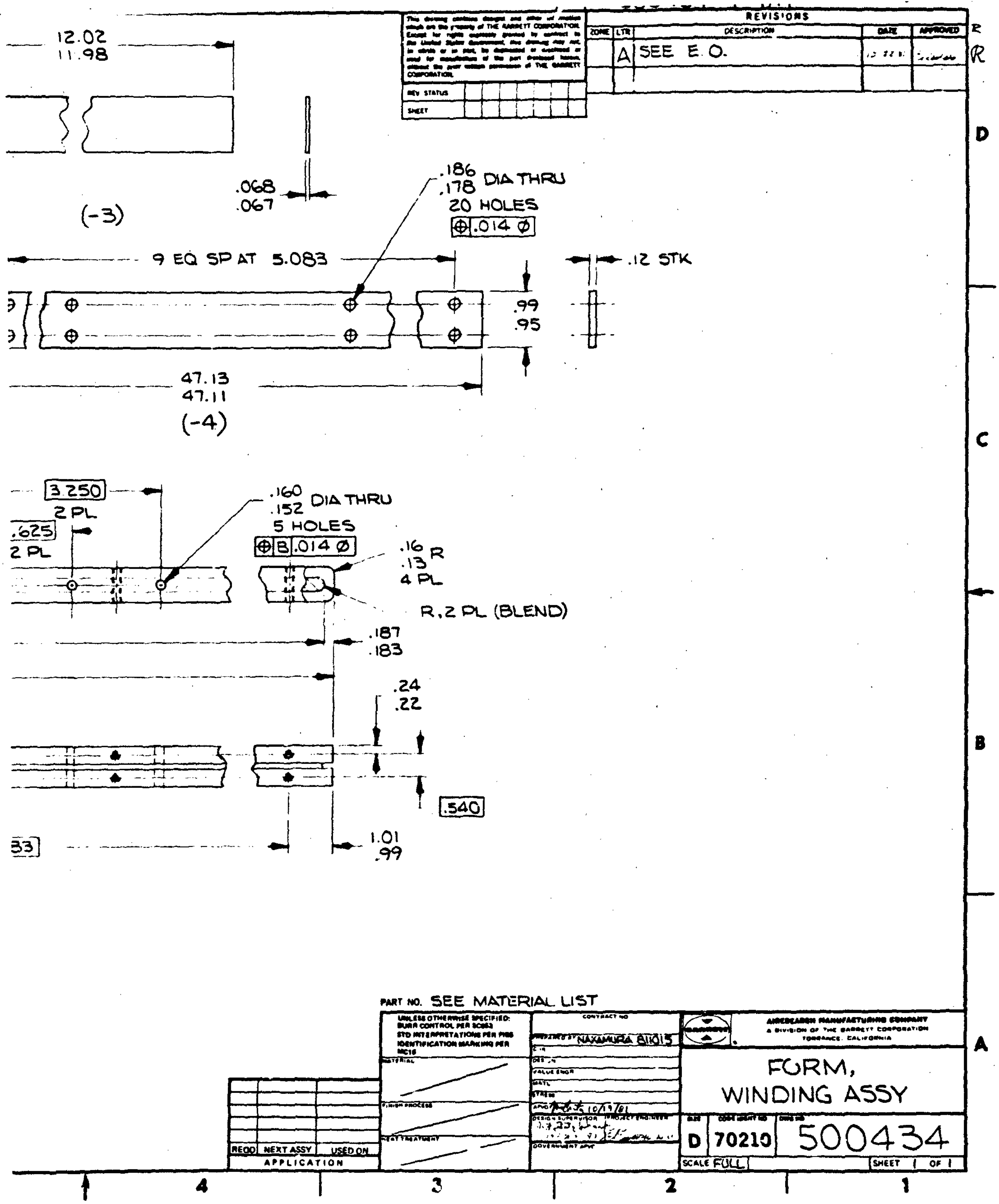
4 3 2 1

3-51/3-52

2

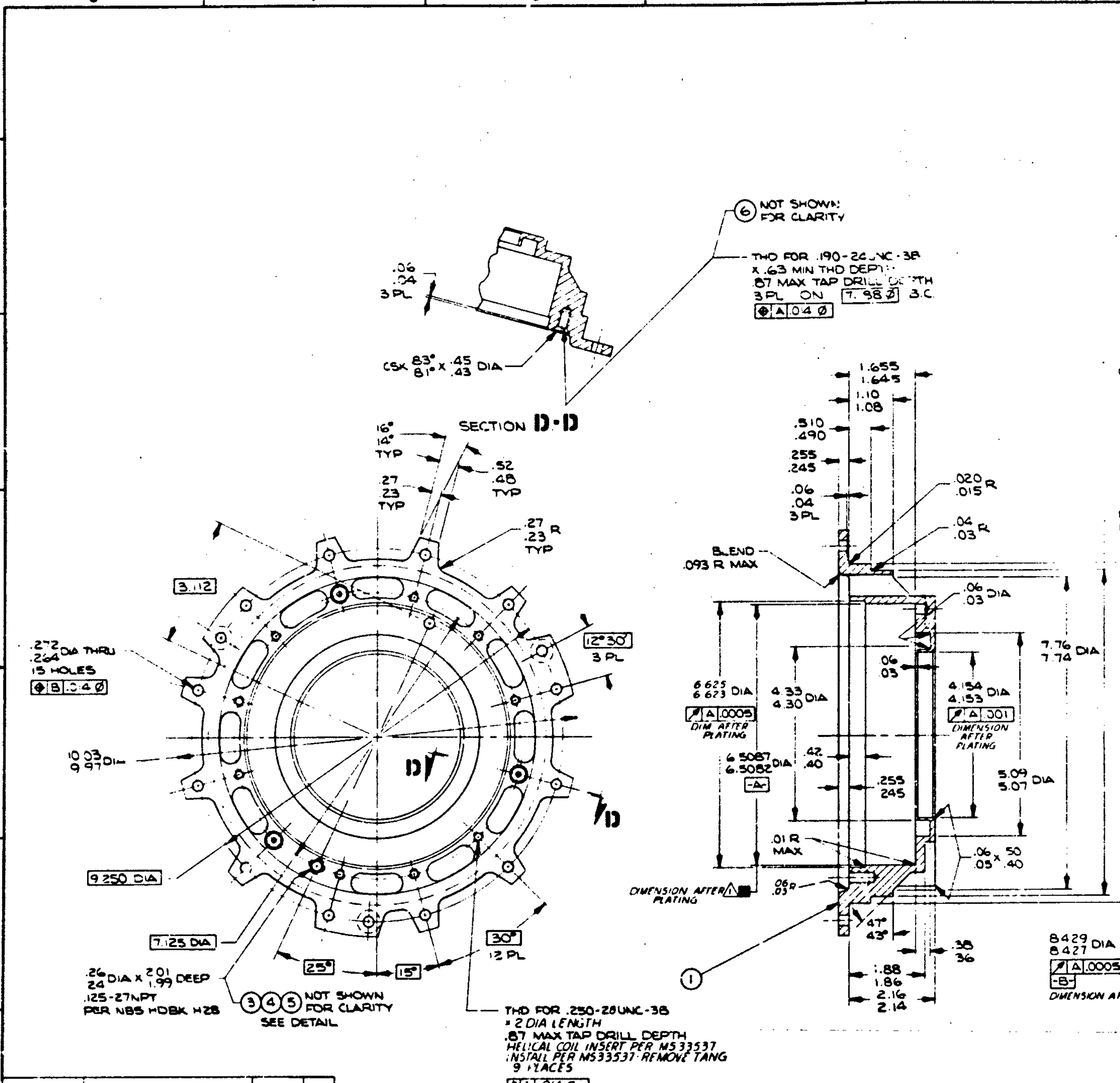


PART NO.	MATERIAL
500434-5	GRADE 1010-1020 STEEL QQ-S-635
500434-4	
500434-3	
500434-2	GRADE 1010-1020 STEEL QQ-S-635
500434-1	AL-ALY 6061-T6 BAR QQ-A-225/8 COND T651


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
A
SEE E.O.
REV STATUS
SHEET
12.02
11.98
.068
.067
(-3)
.186
.178 DIA THRU
20 HOLES
.014 Ø
9 EQ SP AT 5.083
.12 STK
.99
.95
47.13
47.11
(-4)
3.250
2 PL
.625
2 PL
.160
.152 DIA THRU
5 HOLES
B .014 Ø
.16
.13 R
4 PL
R, 2 PL (BLEND)
.187
.183
.24
.22
.540
1.01
.99
D
C
B
A
PART NO. SEE MATERIAL LIST
NAXAMURA 811015
FORM,
WINDING ASSY
D
70210
500434
SCALE FULL
SHEET 1 OF 1
REQD
NEXT ASSY
USED ON
APPLICATION
4
3
2
1

3-53/3-54

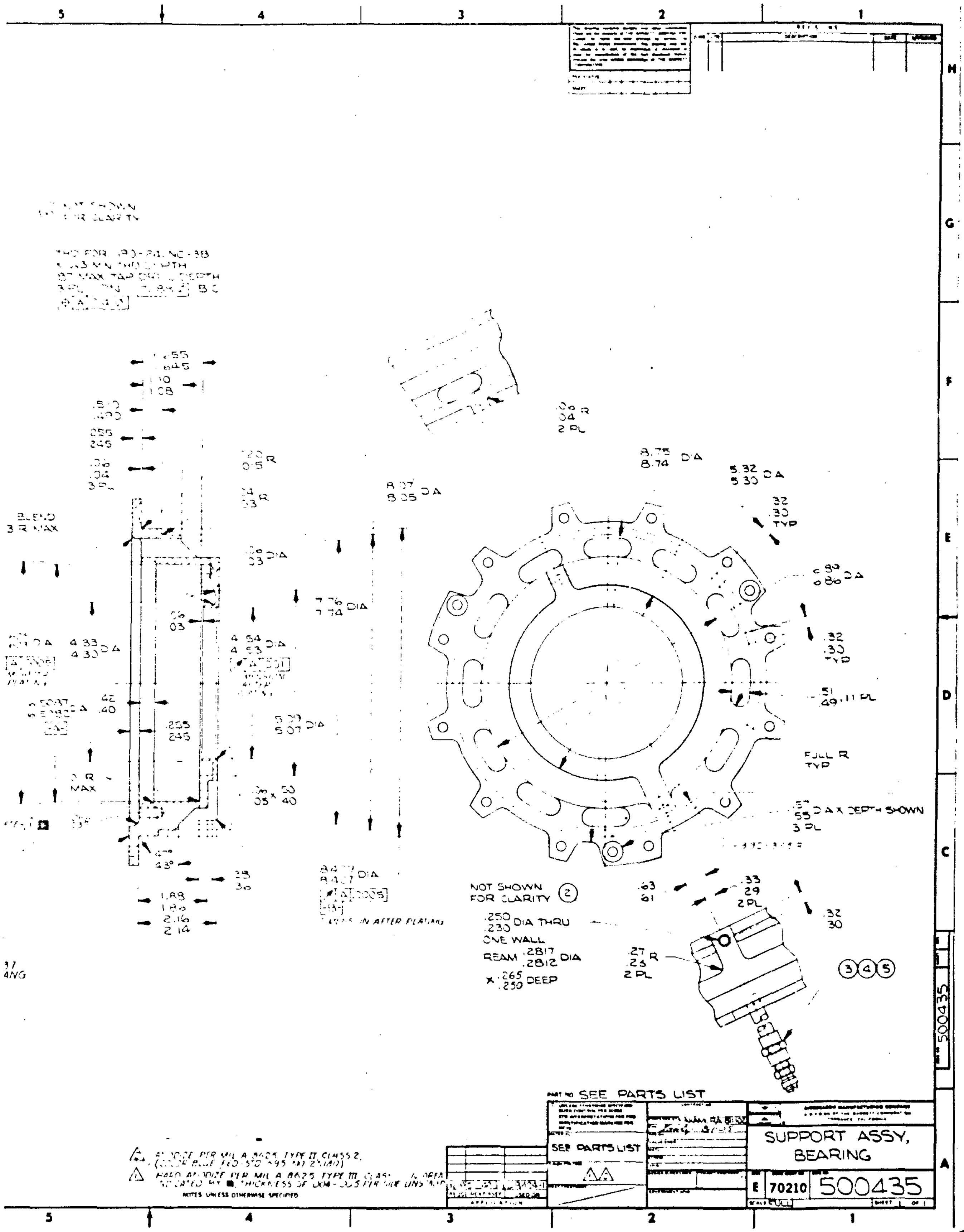
2



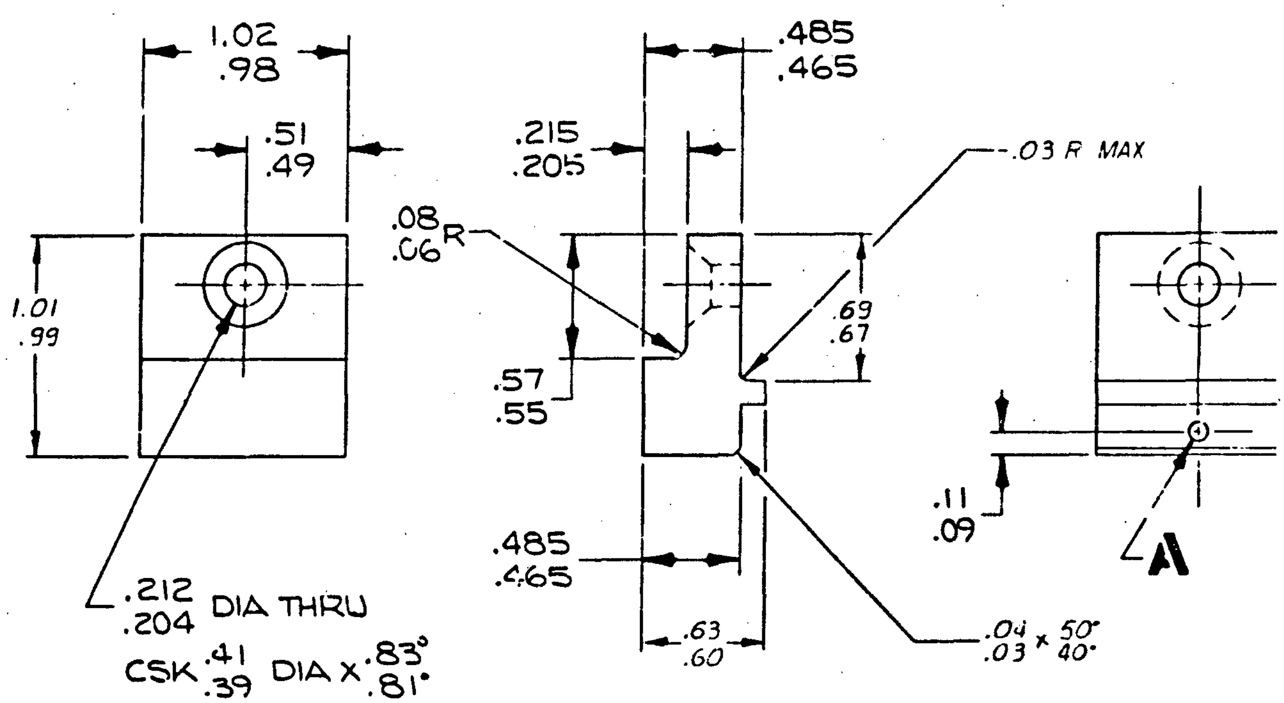
PART NO	MATERIAL / DESCRIPTION	ITEM NO	QTY
MS24 67-19	SCR, CAP-SOC HD, FLAT CSK	6	3
207P-2	COUPLING (PARKER)	5	1
215P2	CLOSE NIPPLE (PARKER)	4	1
2-FBTX-B	MALE CONNECTOR (PARKER)	3	1
572-523-9007	PLUG, SEALING	2	1
500435-1	AL ALY (PLATE) 7075-T7351 QQ-A-250/12 COND T7351	1	1

1. ANODIZE PER MIL-A-8625, TYPE II CLASS 2, (COLOR BLUE FED-STD-595 NO 25180)
2. HARD ANODIZE PER MIL-A-8625 TYPE III CLAS INDICATED BY ■, THICKNESS OF .004-.005 PER S

PLATES UNLESS OTHERWISE SPECIFIED


SEE PARTS LIST
SUPPORT ASSY,
BEARING
E 70210 500435
500435
NOT SHOWN
FOR CLARITY
.250
.230 DIA THRU
ONE WALL
REAM .2817
.2812 DIA
X .265
.250 DEEP
8.75
8.74 DIA
5.32
5.30 DIA
FULL R
TYP
4.33
4.30 DIA
4.54
4.53 DIA
7.76
7.74 DIA
5.09
5.07 DIA
BLEND
.3 R MAX
NOTES: UNLESS OTHERWISE SPECIFIED

DASH NO	A
-1	——
-2	.12/.10 DIA X .31/.29 DEEP



PART NO. SEE TABULATI[ON]

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CLB
STD INTERPRETATIONS PER PI85
IDENTIFICATION MARKING PER MC16

MATERIAL
NEMA GRADE G11
EPOXY GLASS
LAMINATED

FINISH PROCESS

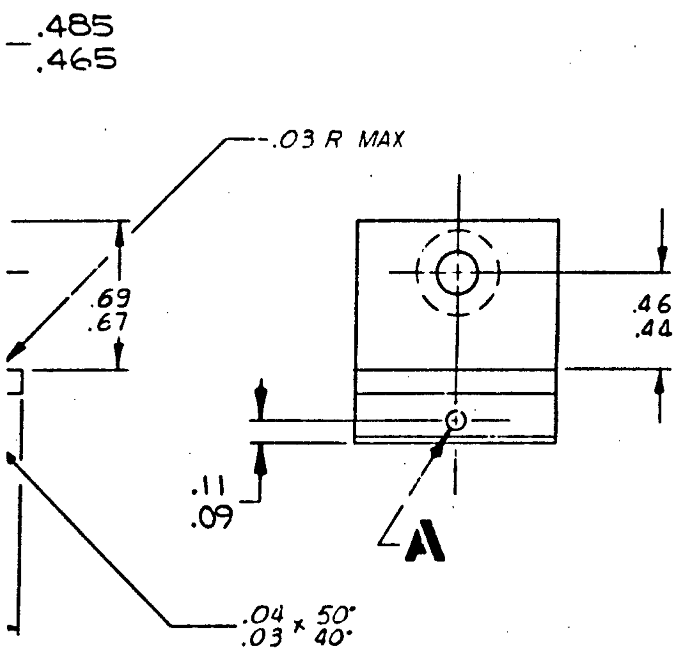
HEAT TREATMENT

2(-2)	500400-1	518404-1
10(-1)	500400-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

PREPARED BY
CHK
DESIGN
VALUE ENGR
MATL
STRESS
APVD
DESIGN SUPER
GOVERNMENT

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

R



500438

RESEARCH
REDUCED SIZE

PART NO. SEE. TABULATION

0-1	518404-1	
0-1	518404-1	
ASSY	USED ON	
APPLICATION		

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CL B
STD INTERPRETATIONS PER PI85
IDENTIFICATION MARKING PER MC16

MATERIAL: NEMA GRADE G11 EFOXY GLASS LAMINATED

FINISH PROCESS

HEAT TREATMENT

CONTRACT NO

PREPARED BY NAKAMURA 8-11-11

CHK 811112

DESIGN

VALUE ENGR

MATL

STRESS

APVD 820109

DESIGN SUPERVISOR 1-26-82

PROJECT ENGINEER

GOVERNMENT APVD

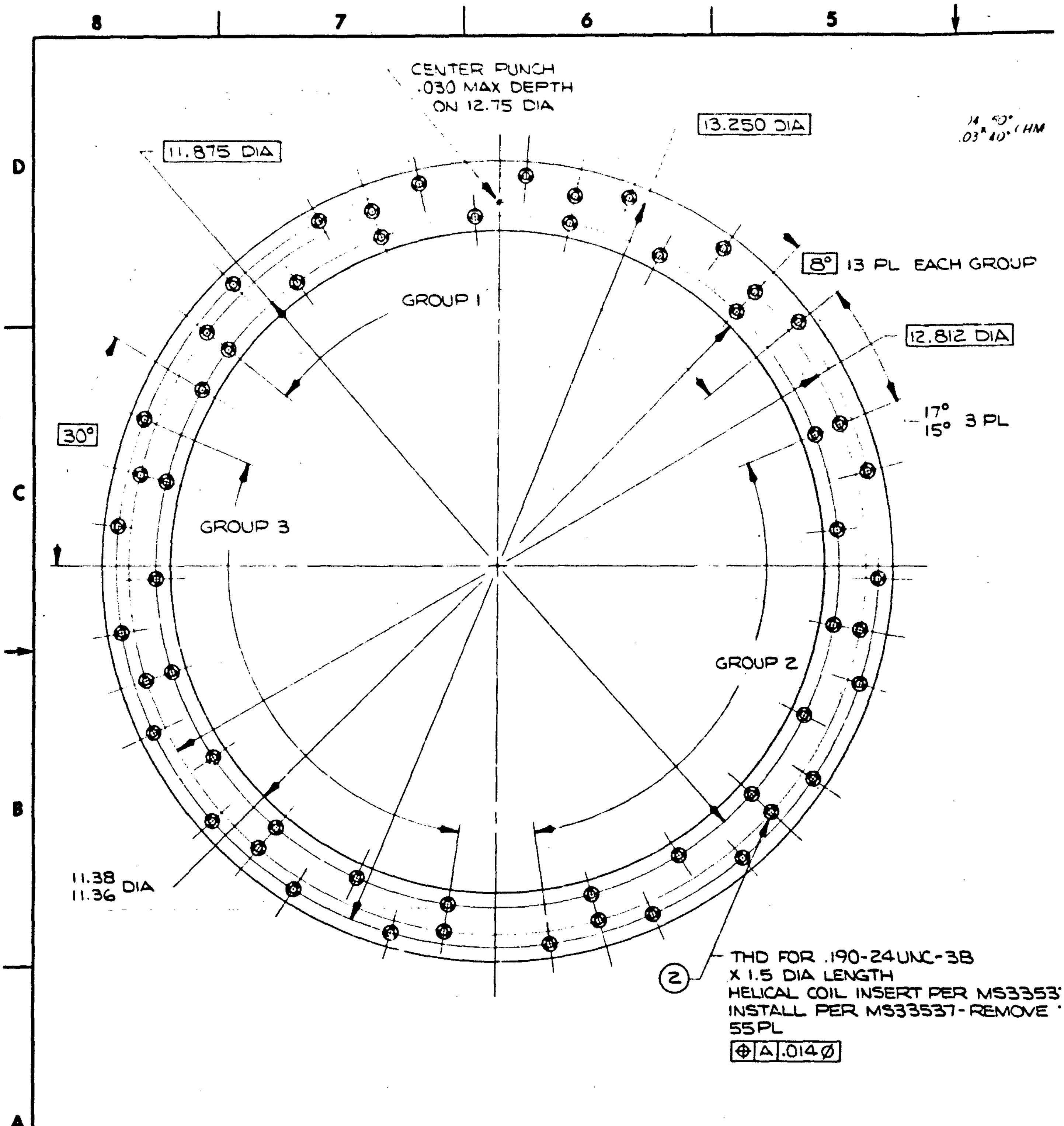
AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

INSULATOR, NEUTRAL RING

SIZE	CODE IDENT NO	DWG NO
C	70210	500438

SCALE 2/1 | SHEET 1 OF 1

2



PART NO	MATERIAL/DESCRIPTION	ITEM NO	QTY
MS21209-C1-15	INSERT SCR THD	2	55
500439-1	13.75 O.D. X 11.37 I.D. AL-ALY PLATE 6061-T6 QQ-A-250/11 COND T651	1	1

DWG NO	SH	REV
500439	1	

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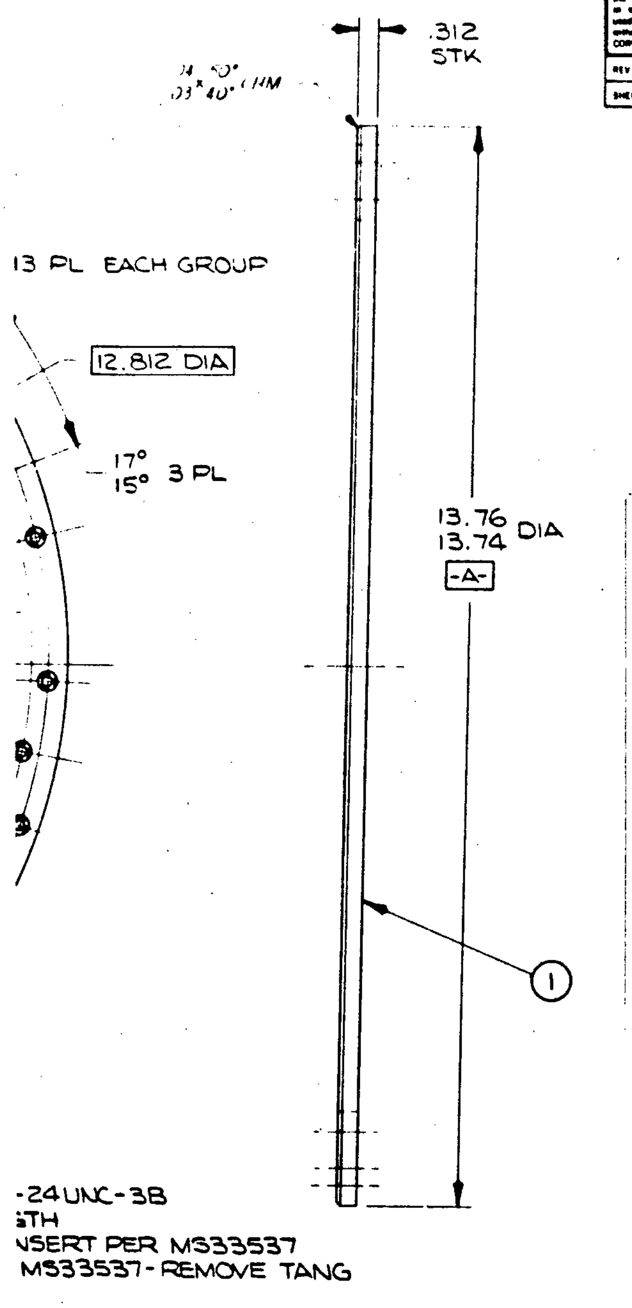
REV STATUS							
SHEET							

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED



PART NO. 500439-1

UNLESS OTHERWISE SPECIFIED
BURR CONTROL PER SC653 CL B
STD INTERPRETATIONS PER PI98
IDENTIFICATION MARKING PER MC16

MATERIAL: SEE TABULATION

FINISH PROCESS

HEAT TREATMENT

1(-1)	500400-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

CONTRACT NO

PREPARED BY NAKAMURA 8/10/11

CHK

DESIGN

VALUE ENGR

MATL

STRESS

APVD

DESIGN ACTIVITY APVD

PROJECT ENG

GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

RING, NEUTRAL

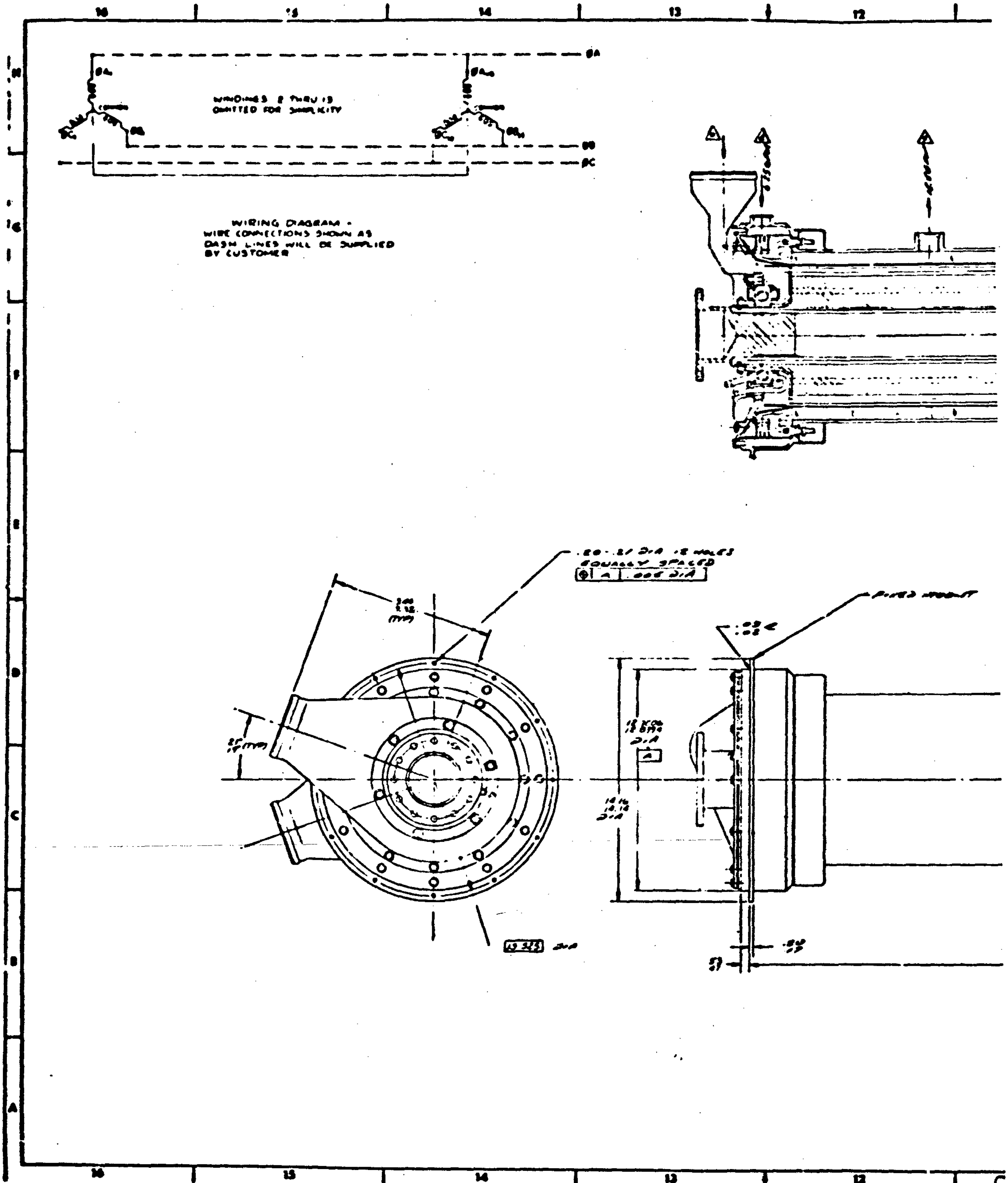
SIZE	CODE IDENT NO	DWG NO
D	70210	500439

SCALE FULL

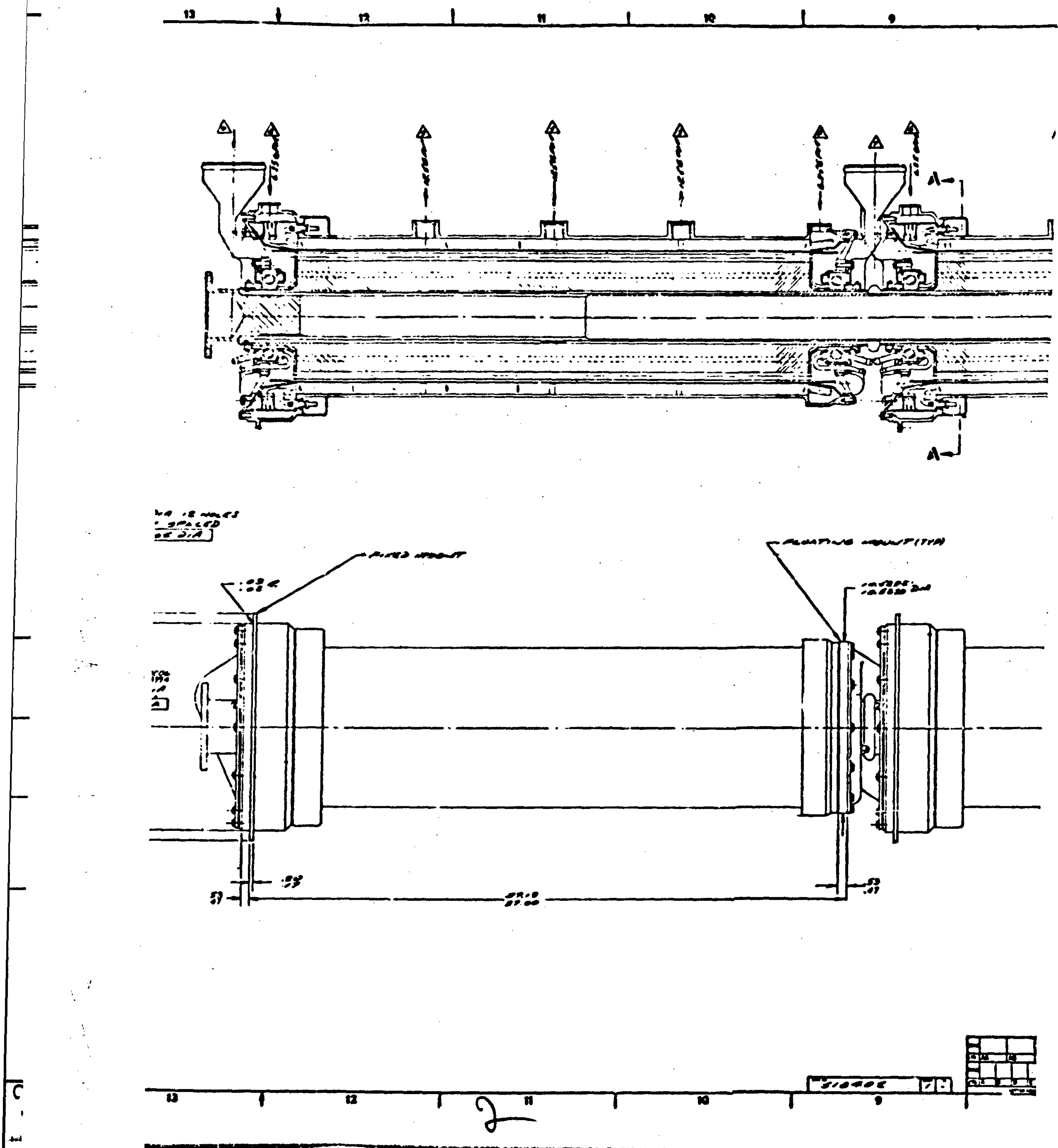
SHEET 1 OF 1

2

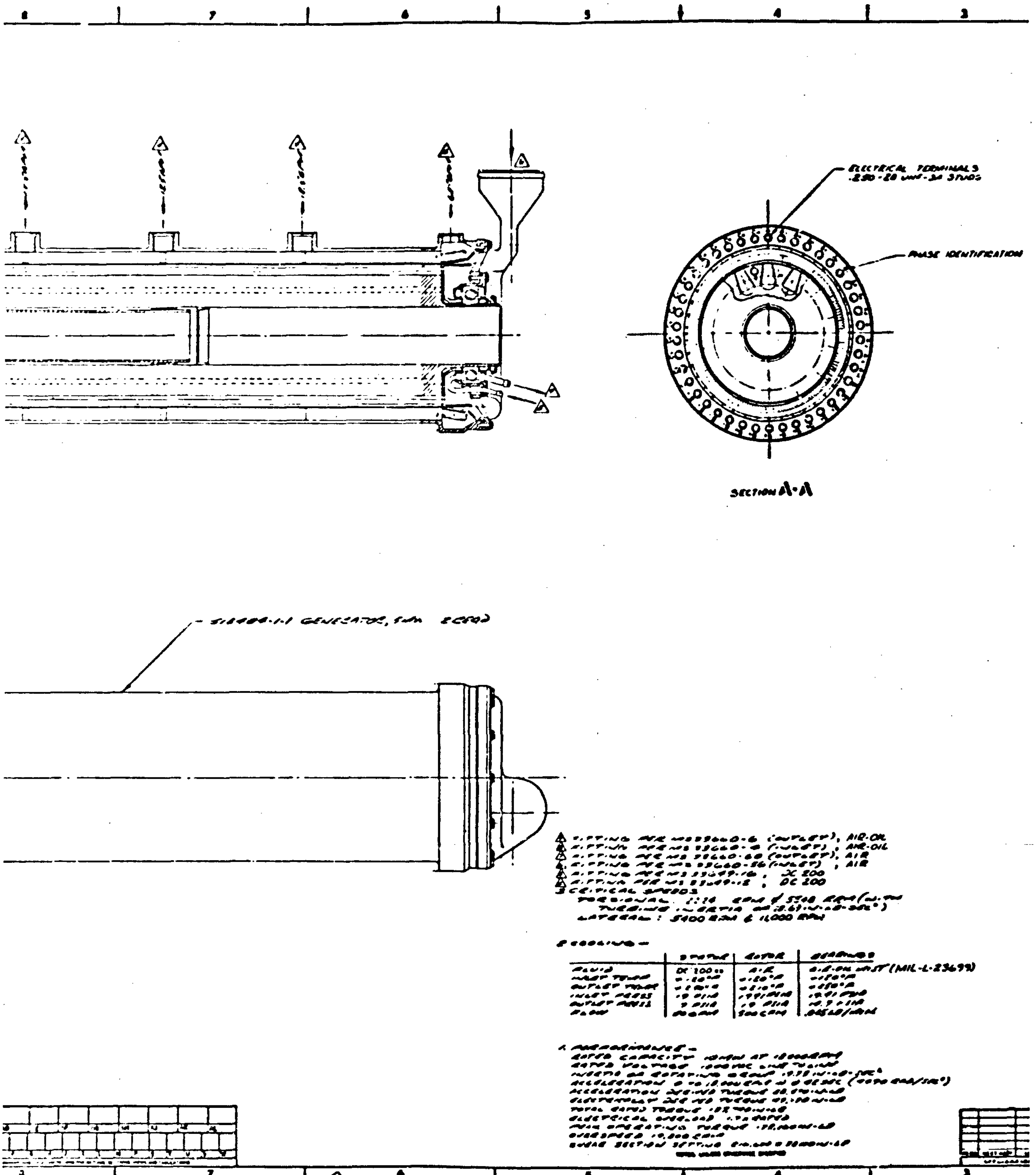
3-59/3-60



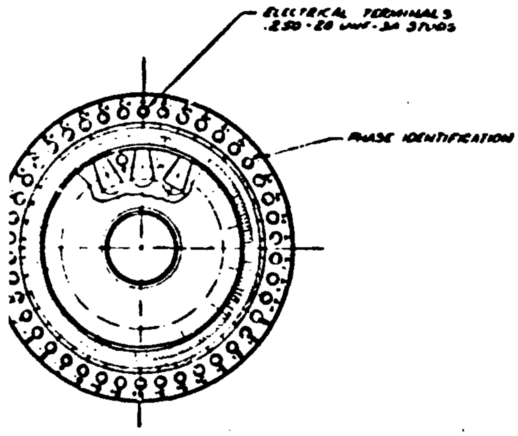
WINDINGS 2 THRU 13
OMITTED FOR SIMPLICITY
WIRING DIAGRAM -
WIRE CONNECTIONS SHOWN AS
DASH LINES WILL BE SUPPLIED
BY CUSTOMER
.20-.21 DIA 12 HOLES
EQUALLY SPACED
FIXED MOUNT



13
12
11
10
9
A
FIXED MOUNT
FLOATING MOUNT (TYP)


ELECTRICAL TERMINALS
PHASE IDENTIFICATION
SECTION A-A
GENERATOR
AIR-OIL
AIR-OIL
AIR
AIR
CRITICAL SPEEDS
LATERAL : 5400 RPM & 11,000 RPM
(MIL-L-23699)

37



SECTION A-A

[illegible]9660-6 (OUTLET), AIR-OIL
[illegible]93660-[illegible] (INLET), AIR-OIL
[illegible]93660-60 (OUTLET), AIR
[illegible]93660-56 (INLET), AIR
[illegible]; [illegible] 200
[illegible]; DC 200
[illegible]
[illegible] RPM & 5500 RPM (WITH
[illegible]
900 RPM & 11,000 RPM

[illegible]	ROTOR	[illegible]
[illegible] 200	AIR	AIR-OIL MIST (MIL-L-23699)
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible] PSIA	[illegible] PSIA	[illegible] PSIA
[illegible] PSIA	[illegible] PSIA	[illegible] PSIA
[illegible]	500 CFM	.045 LB/MIN

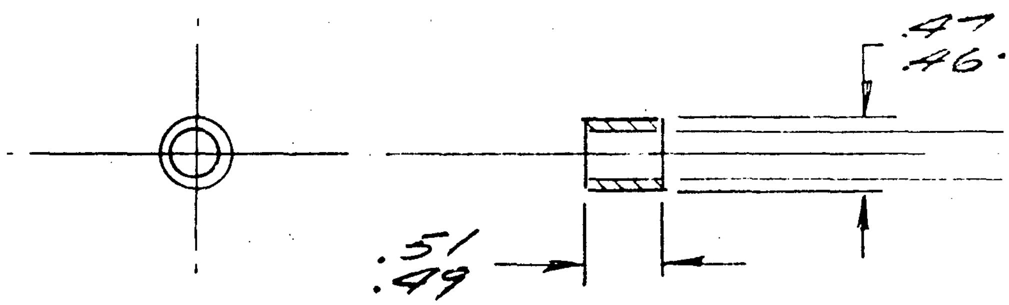
[illegible] AT [illegible] RPM
[illegible]
[illegible]
[illegible]
[illegible]

PART NUMBER	ASSEMBLY NUMBER	
518402-1-1	518403-1	

GENERATOR SYSTEM 10MW

J | 70210 | 518402

DWG NO 2046



PART NO 2046855-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CLB
STD INTERPRETATIONS PER PIB5
IDENTIFICATION MARKING PER
MC16

AR(-1)	2046850-	2046870
REQD	NEXT ASSY	USED ON
APPLICATION		

MATERIAL

NOTE 1

HEAT TREATMENT

FINISH PROCESS

CONTR

CHK

VALUE

MATL

STRES

DESIG

PROJE

GOVER

1. MATL: .50 DIA BAR
ASTM A 582 TYPE 303

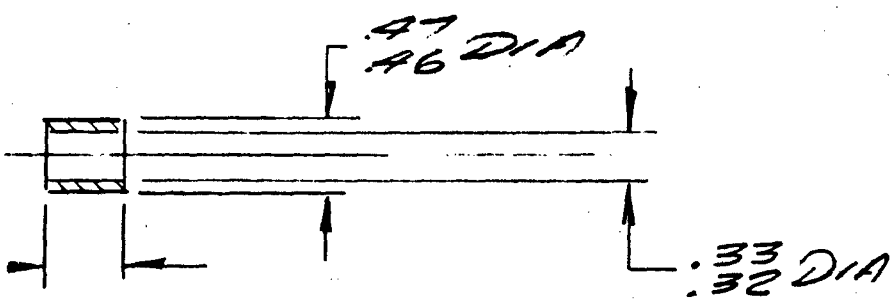
NOTES

FORM 1196 (1-77)

DWG NO 2046855 | SH

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

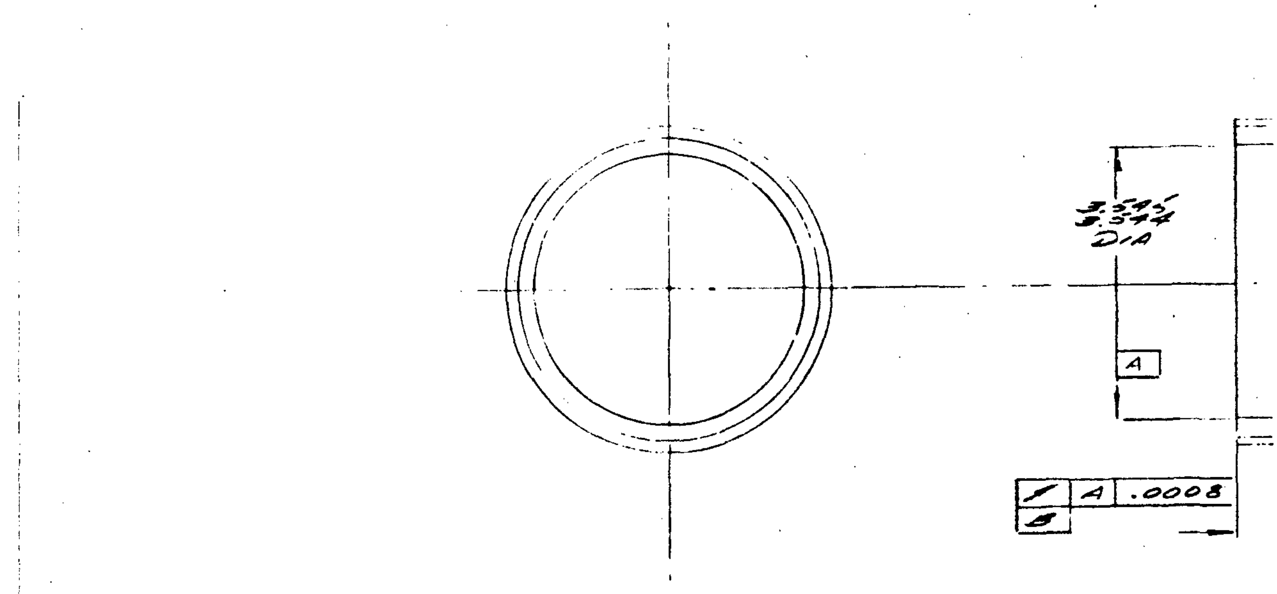


855-1

ECIFIED: 853 CLB PER P185 ING PER	MATERIAL NOTE 1	CONTR NO	AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA
		DRAWN 4-18-78	
		CHK 5-9-78	WEIGHT BALANCE
		VALUE ENGR	
		MATL	
	HEAT TREATMENT	STRESS	
46870		DESIGN SUPERVISOR 820109	SIZE B · CODE IDENT NO 70210 · DWG NO 2046855
ISED ON	FINISH PROCESS	PROJECT ENGINEER 1-12-82	SCALE 1-1 · SHEET 1 OF 1
		GOVERNMENT APVD	

2

3-63/3-64

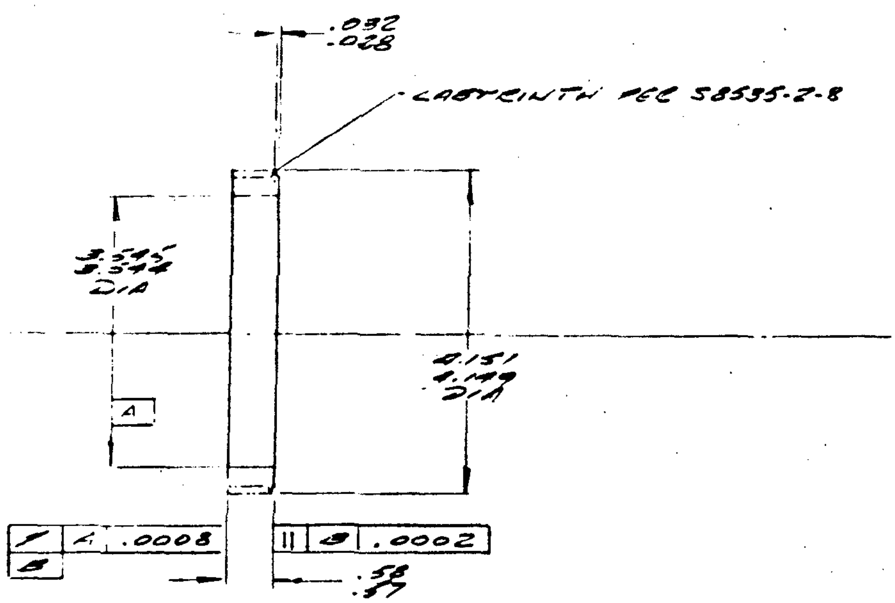


1. FINISH AA 125
NOTES

DWG NO 2046874 | SH 1 | REV

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPR

REV STATUS
SHEET



PART NO 2046874-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER S0000 CL B; STD INTERPRETATIONS FOR PMS IDENTIFICATION MARKING PER MC10

4.25 OD x .375 WALL 1015
QQ-T-830
QQ-P-416
TYPE I, CL 3

-1	2046870	2046870
REQD	NEXT ASSY	USED ON
APPLICATION		

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

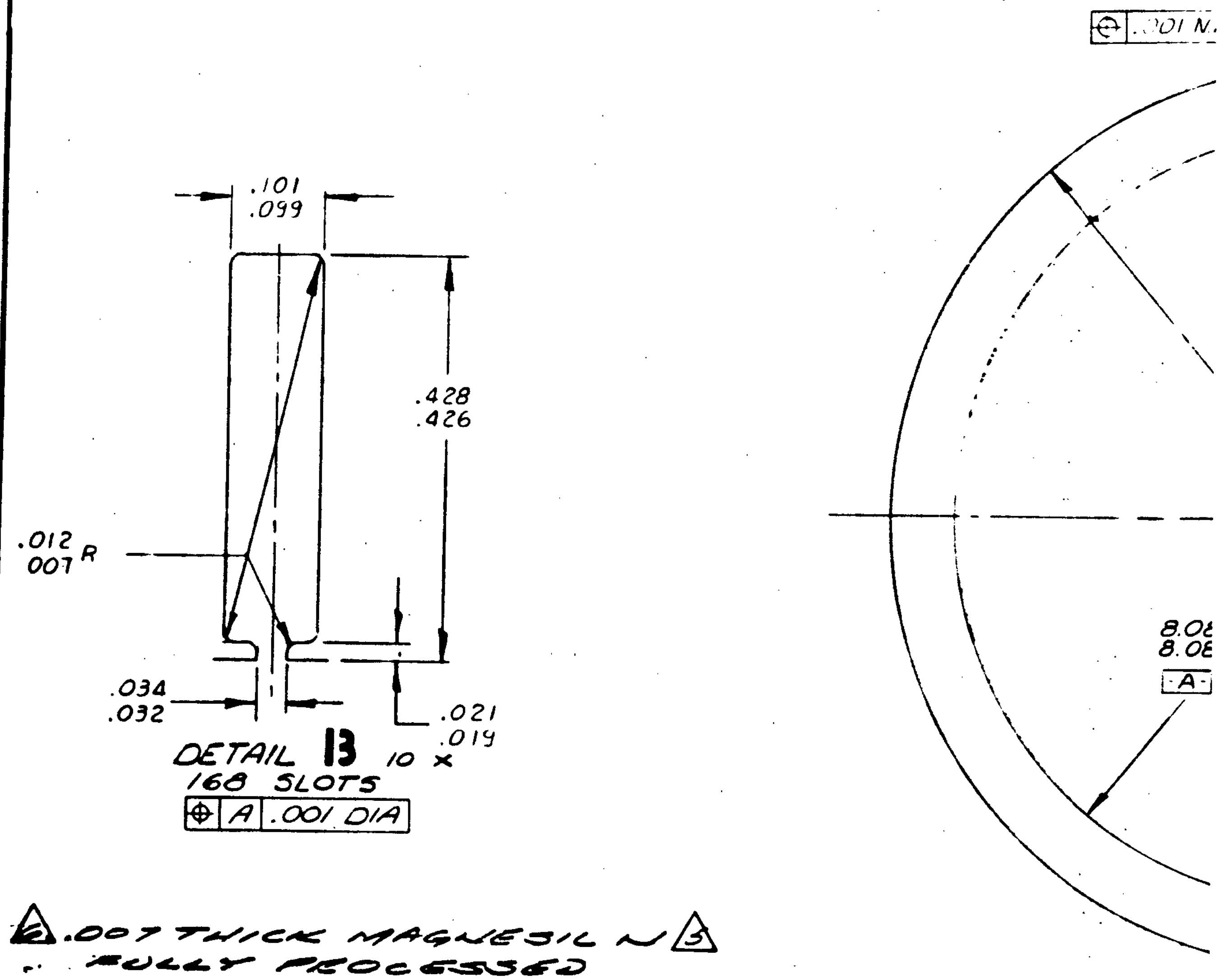
SPACER

D | 70210 | 2046874

SCALE FULL | SHEET 1

3-65/3-66 2

PART NO.	MATERIAL
2096875-1	6
2096875-2	SYNTHETIC FIBER PAPER (NOMEX) MIL-I-24204 TYPE I .020 THICK



6 .007 THICK MAGNESIL N 5
FULLY PROCESSED
UNCOATED
5 MAGNETICS, BUTLER, PA. FSC 90797

3 ANNEAL AFTER PUNCHING PER HT 59, TYPE I. INERT GAS ONLY. NO PACK ANNEAL.
2. LAMINATIONS SHALL BE FLAT WITHIN .005 UNDER 5 LB LOAD
1. BURRS SHALL NOT EXCEED .0007 AS PUNCHED
NOTES

PART NO TABULATED

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER BCSS ..8
STD INTERPRETATIONS PER PI55
IDENTIFICATION MARKING PER MC16

MATERIAL: TABULATED

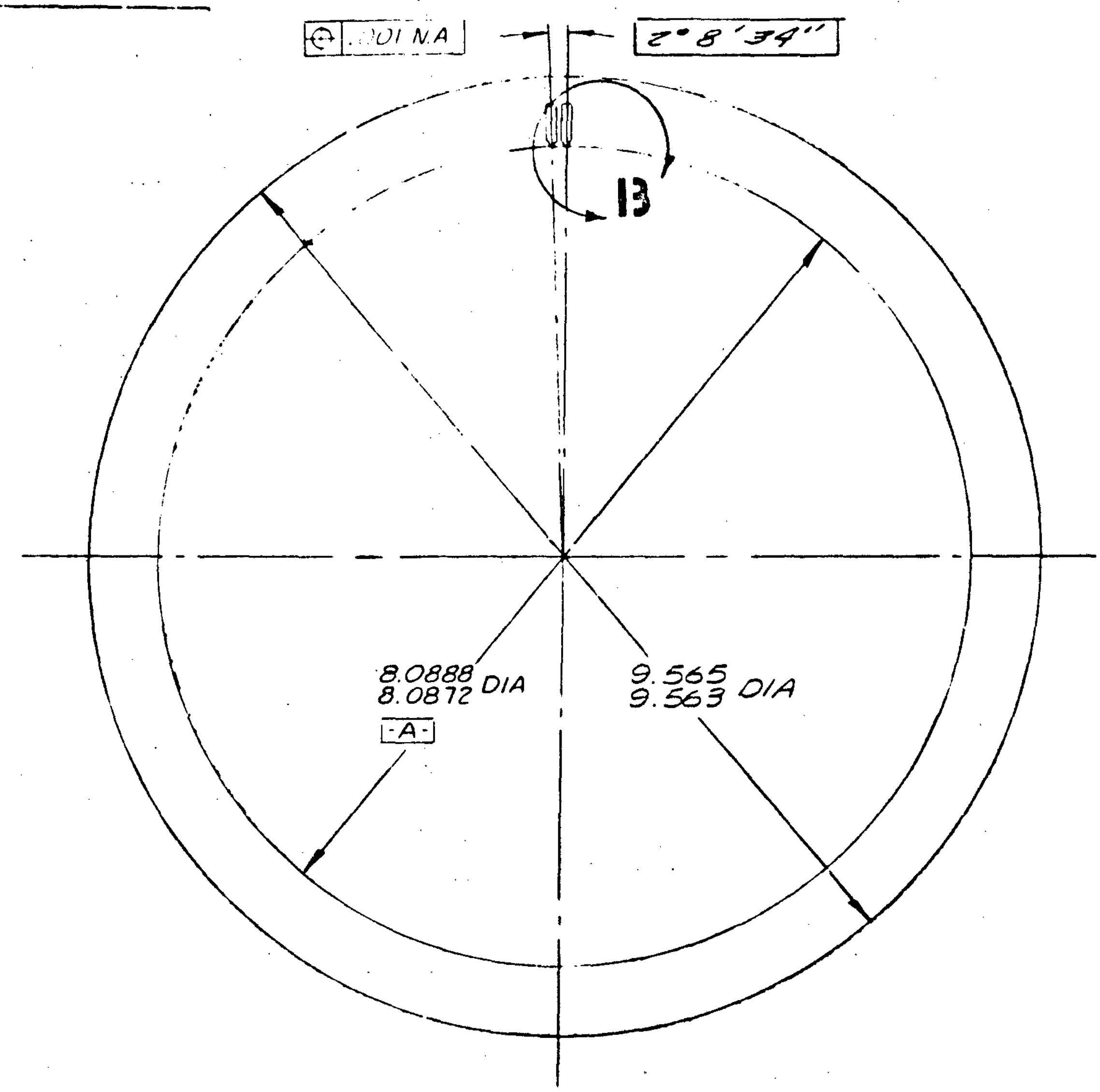
FINISH PROCESS: ——

HEAT TREATMENT: 3

PROD	NEXT ASSY	USED ON
-1	2096960	
-2	2096960	

APPLICATION

REVISIONS				
ZONE	LTR	DESCRIPTION		



PART NO TABULATED

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC583 CL8
STD INTERPRETATIONS PER PI55
IDENTIFICATION MARKINGS PER MC16

MATERIAL
TABULATED

FINISH PROCESS
———

CONTRACT NO
DESIGN
VALUE ENGR
MATL
STRESS

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

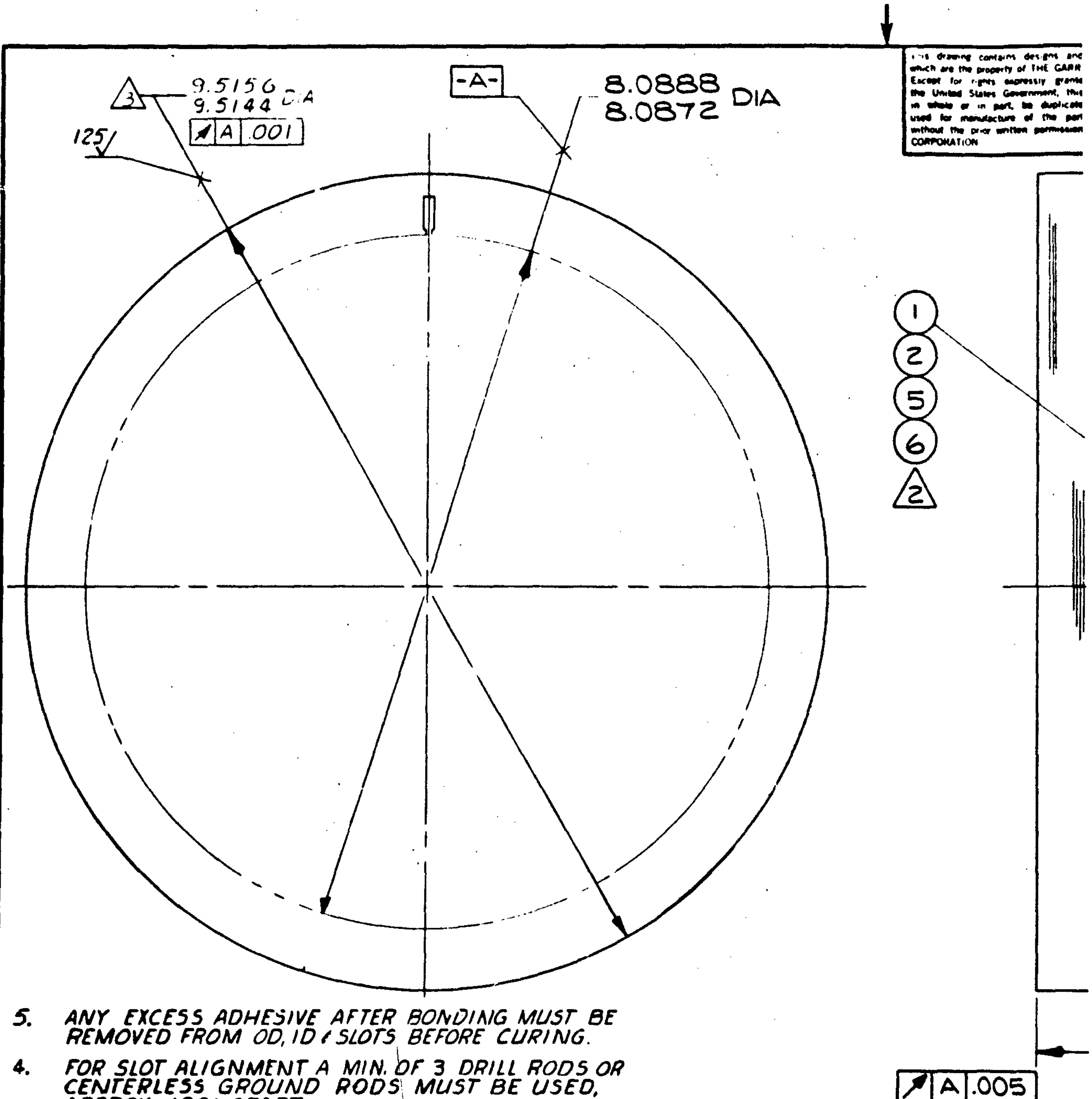
LAMINATION
STATOR, GEN.

SIZE	CODE IDENT NO	DWG NO
C	70210	2046875

SCALE FULL

NEXT ASSY | USED ON
APPLICATION

3-67/3-68



5. *ANY EXCESS ADHESIVE AFTER BONDING MUST BE REMOVED FROM OD, ID & SLOTS BEFORE CURING.*

4. *FOR SLOT ALIGNMENT A MIN. OF 3 DRILL RODS OR CENTERLESS GROUND RODS MUST BE USED, APPROX. 120° APART.*

3. *PROCESS PER FP13AC3B EXCEPT COLD BRUSH PHOSPHATE ONLY PER FP15 FOR APPLICATION OF DRY FILM LUBE TO I.D.*

2. *FIND NO. 5&6 TO HAVE 24.00 LB OF ACTUAL STEEL WEIGHT TO INSURE SUFFICIENT IRON CONTENT BEFORE MACHINING.*

1. APPLY INSULATING COAT OF FIND 2 .0003-.0005 THICK TO FIND 1, & THROUGHLY CURE. APPLY BONDING COAT OF FIND 2 TO FIND 1 & STACK FIND 5&6 WITH SLOTS ALIGNED WITHIN .001. *PER RS 25*

NOTES: UNLESS OTHERWISE SPECIFIED.

REQD	NEXT ASSY	USED ON
2(-2)	500400-1	518404-1
2(-1)	500400-1	518404-1

APPLICATION

PART NO. SEE SEP

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC863 CL B
STD INTERPRETATIONS PER P186
IDENTIFICATION MARKING PER MC16

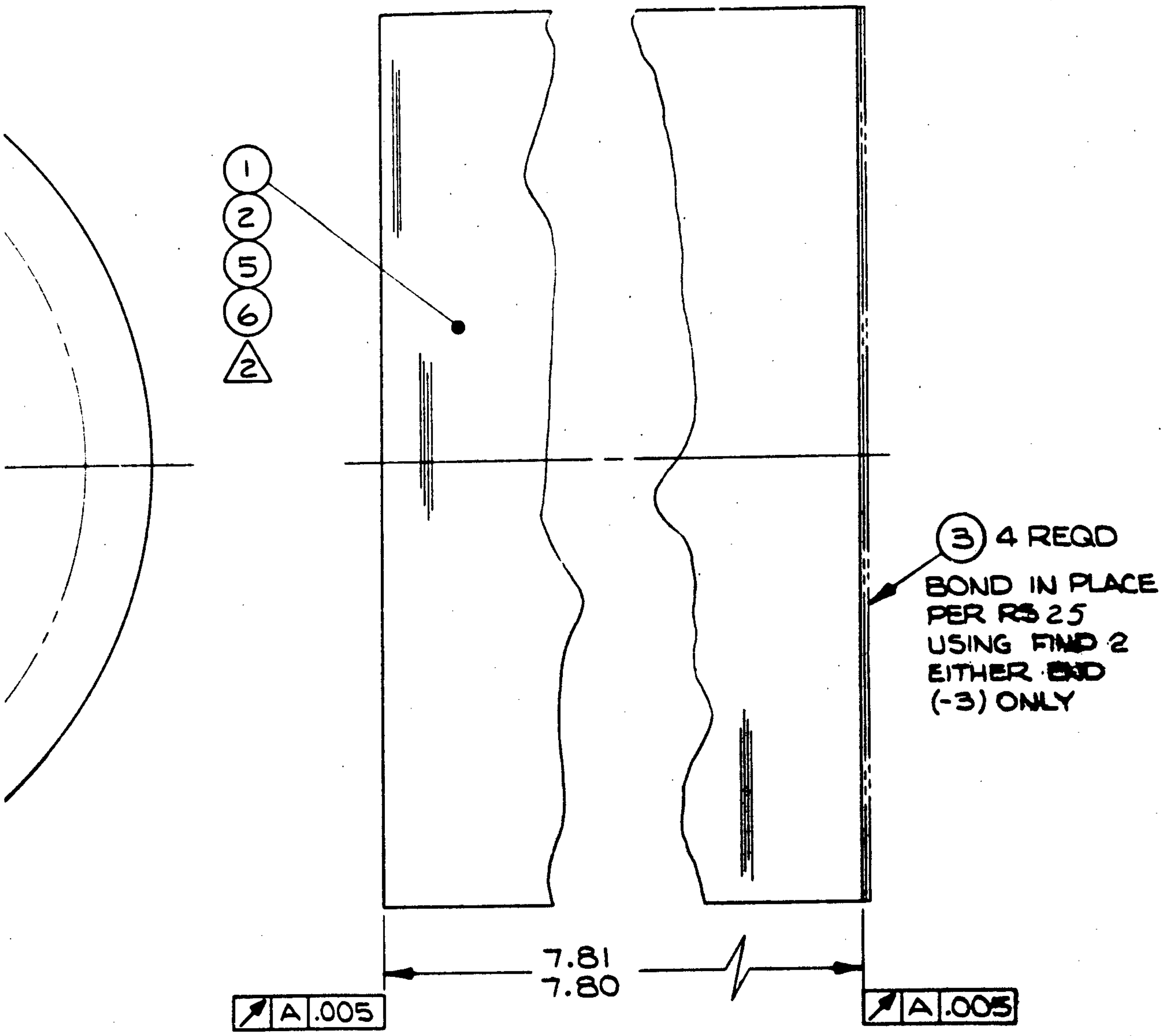
MATERIAL

FINISH PROCESS 3

HEAT TREATMENT

This drawing contains designs and other information which are the property of THE GARRETT CORPORATION. Except for rights expressly granted by contract to the United States Government, this drawing may not, in whole or in part, be duplicated or disclosed or used for manufacture of the part disclosed herein, without the prior written permission of THE GARRETT CORPORATION.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



PART NO. SEE SEPARATE PARTS LIST

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC663 CLB
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER MC16

MATERIAL

FINISH PROCESS 3

HEAT TREATMENT

CONTRACT NO

PREPARED BY NAKAMURA 811112
CHK 811113
DESIGN
VALUE ENGR
MATL
STRESS
APVD 820109
DESIGN SUPERVISOR
PROJECT ENGINEER
GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

STACK ASSY STATOR

SIZE	CODE IDENT NO	DWG NO
C	70210	2046960

SCALE FULL SHEET 1 OF 1

20400-1	518404-1
20400-1	518404-1
NEXT ASSY	USED ON

APPLICATION

2

3-69/3-70

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the United States Government, this draw
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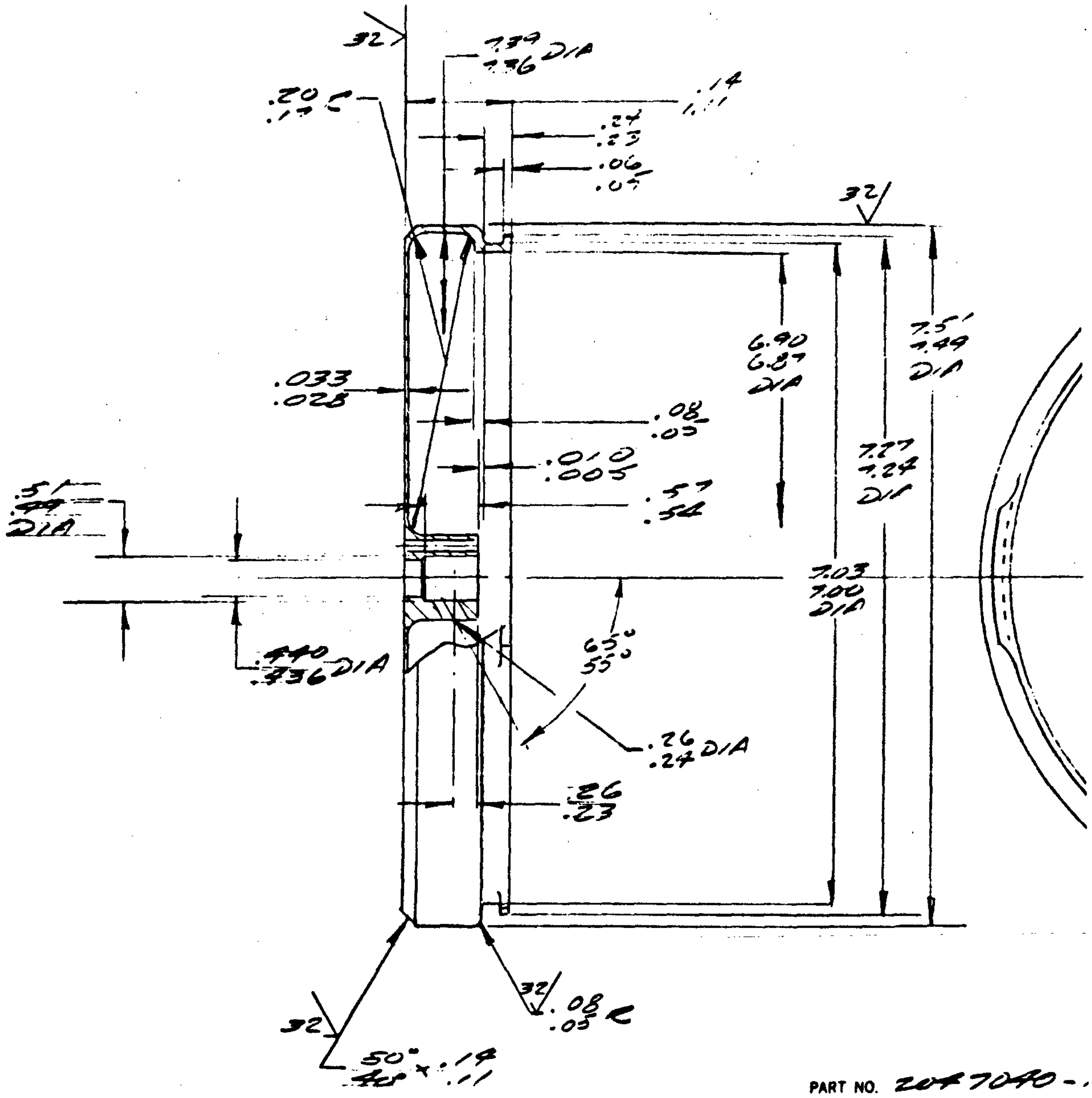
used for manufacture of the part discl
without the prior written permission of T
CORPORATION.



PART NO. 2047040-

UNLESS OTHERWISE SPECIFIED:
BU R CONTROL PER SC653 CLB
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER
MC16

MATERIAL
7.50 DIA AL ALY
BAR
6061-T6

FINISH PROCESS

HEAT TREATMENT

(-1)		
REQD	NEXT ASSY	USED ON
APPLICATION		

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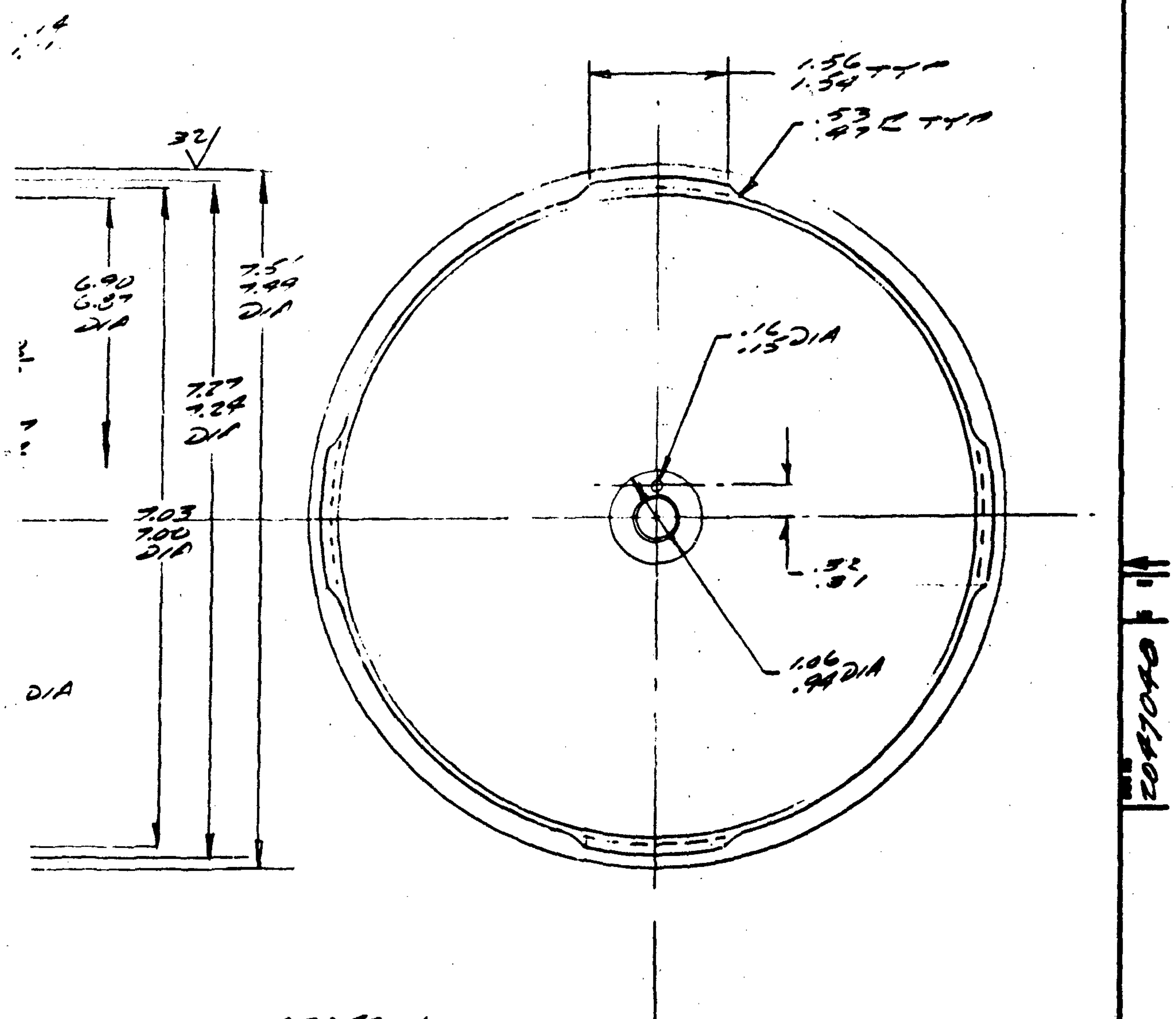
REVISIONS				
ZONE	LTR	DESCRIPTON	DATE	APPROVED

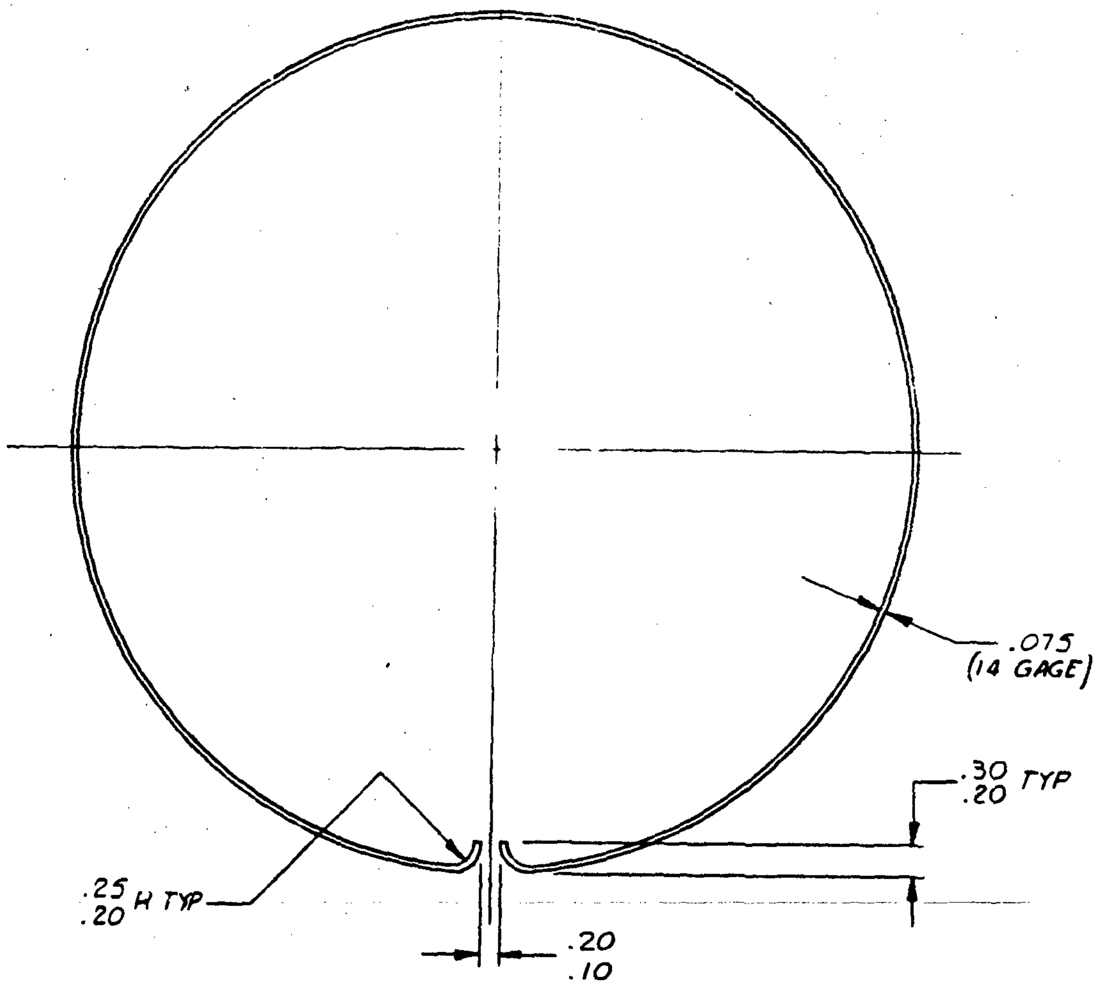
OR



PART NO. 2047040-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC663 CLB STD INTERPRETATIONS PER PI86 IDENTIFICATION MARKING PER MC16	CONTRACT NO	AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA
MATERIAL 7.50 DIA AL ALY BAR 6061-T6	PREPARED 8-28-78	TOOL END CAP, BORE SEAL
FINISH PROCESS	CHK 820111	
HEAT TREATMENT	DESIGN	
USED ON	VALUE ENGR	
ON	MATL	
	STRESS	
	APVD 820104	
	DESIGN SUPERVISOR / PROJECT ENGINEER	SIZE C / CODE IDENT NO 70210 / DWG NO 2047040
	GOVERNMENT APVD	SCALE FULL / SHEET 1 OF 1

2



PART NO. 2047043-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC863 CLB
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER MC18

MATERIAL
AL ALY 6061-T6
QQ-A-250/11 COND T6

FINISH PROCESS

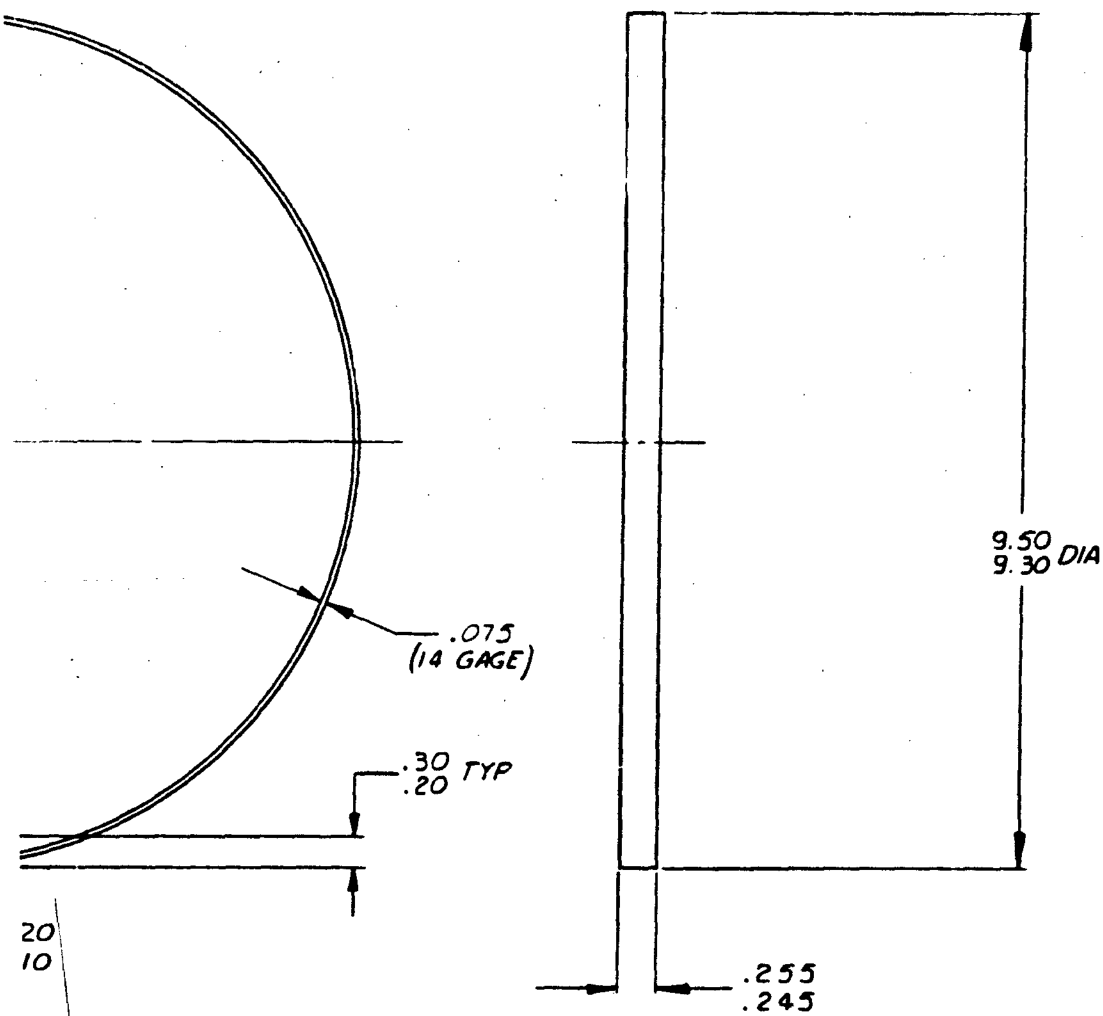
HEAT TREATMENT

3(-1)	2046890-1	2047042-1
REQD	NEXT ASSY	USED ON
APPLICATION		

2 THIS PART WILL BE REMOVED AFTER NEXT ASSY.
1. FINISH 125 ALL OVER
NOTES: UNLESS OTHERWISE SPECIFIED

REVISIONS

ZONE	LTR	DESCRIPTON	DATE	APPROVED



2047043

PART NO. 2047043-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC863 CLB
STD INTERPRETATIONS PER P186
IDENTIFICATION MARKING PER MC16

MATERIAL
AL ALY 6061-T6
QQ-A-250/11 COND T6

FINISH PROCESS

HEAT TREATMENT

CONTRACT NO

PREPARED BY C DUNMIRE
CHK Harty 820107
DESIGN
VALUE ENGR
MATL
STRESS
APVD 820108
DESIGN SUPERVISOR
PROJECT ENGINEER 1-12-82
GOVERNMENT APVD

2046890	2047042-1
NEXT ASSY	USED ON
APPLICATION	

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

SPACER

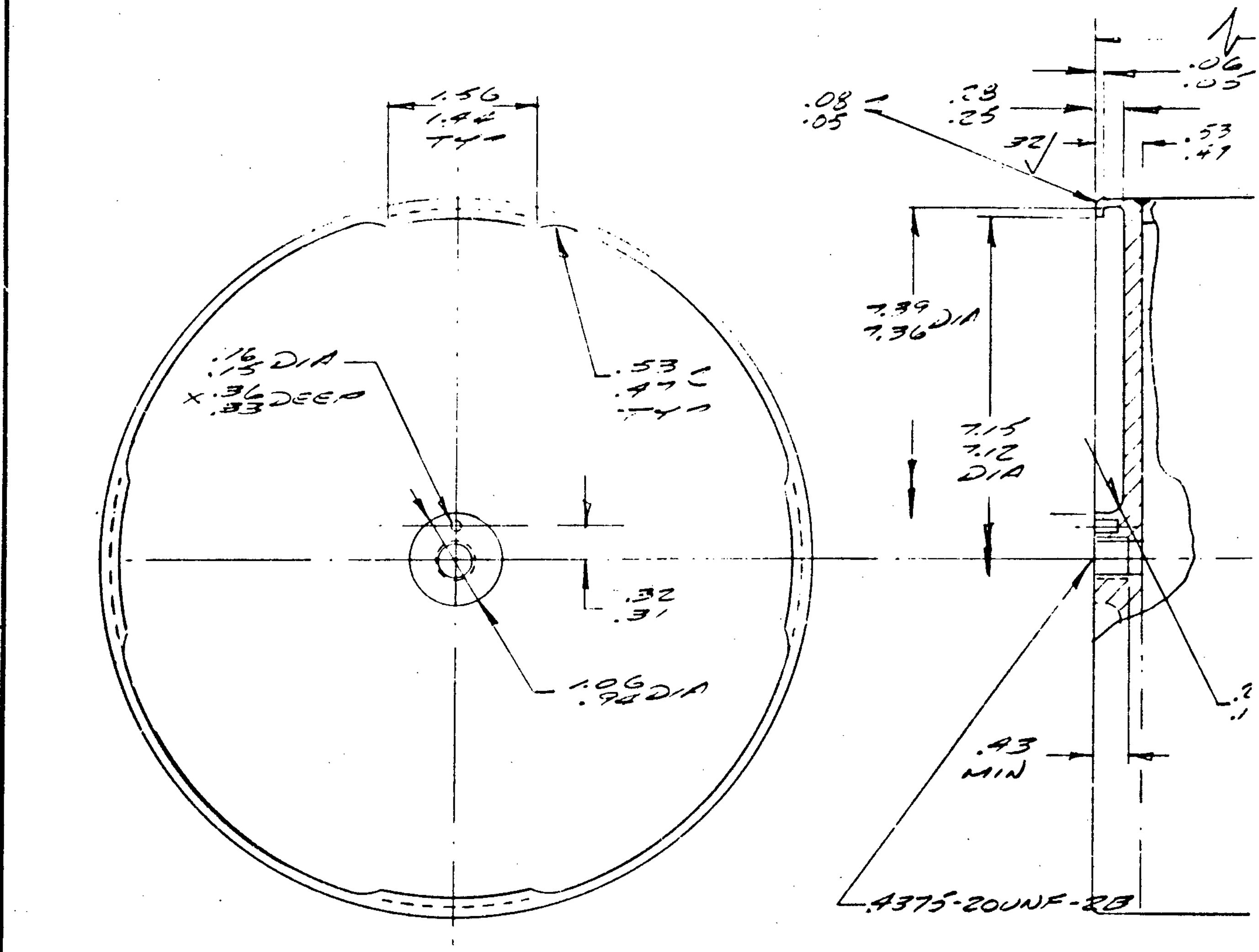
SIZE	CODE IDENT NO	DWG NO
C	70210	2047043

SCALE: 1/1 SHEET 1 OF 1

2

3-73/3-74

PART NO	A
2047176-1	21.80-22.05
2047176-2	40.00 - 41.00



PART NO. 2047176-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CLB
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER MC16

MATERIAL
NOTE 1

FINISH PROCESS
—

HEAT TREATMENT
—

1(-1)		
REQD	NEXT ASSY	USED ON
APPLICATION		

1. MAT'L
BODY 7.50 x .25 WALL 6061 TUBE
ENDCAPS .50 6061 PLATE

NOTES

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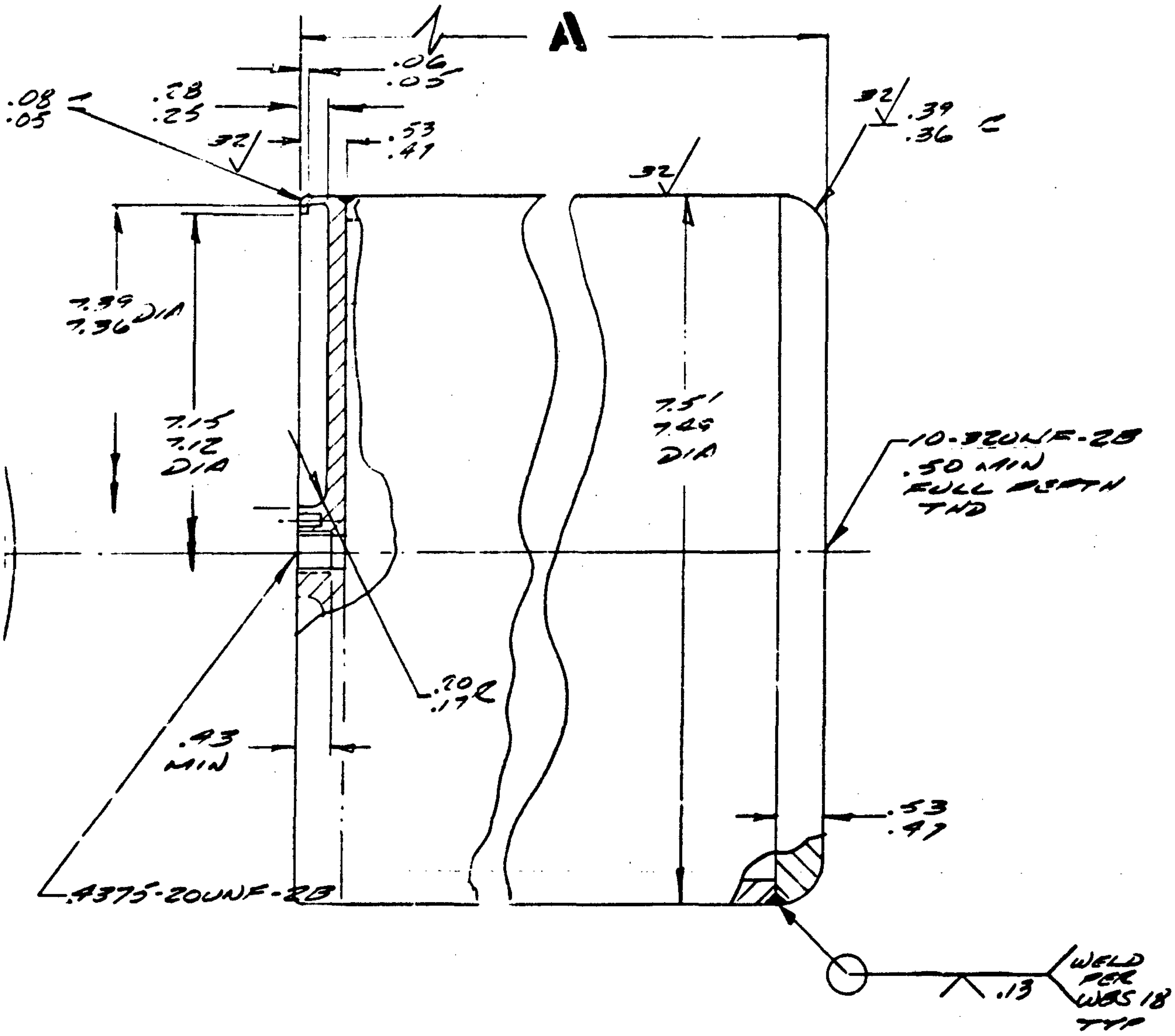
REVISIONS				
ZONE	LTR	DESCRIPTON	DATE	APPROVED

OR



2047176

PART NO. 2047176-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC653 CLB STD INTERPRETATIONS PER PI86 IDENTIFICATION MARKING PER MC16	CONTRACT NO
MATERIAL NOTE 1	DRN 8-28-78
	CHK 820111
	DESIGN
	VALUE ENGR
	MATL
	STRESS
FINISH PROCESS —	APVD
	DESIGN SUPERVISOR / PROJECT ENGINEER
HEAT TREATMENT —	GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

TOOL BODY
BORE SEAL

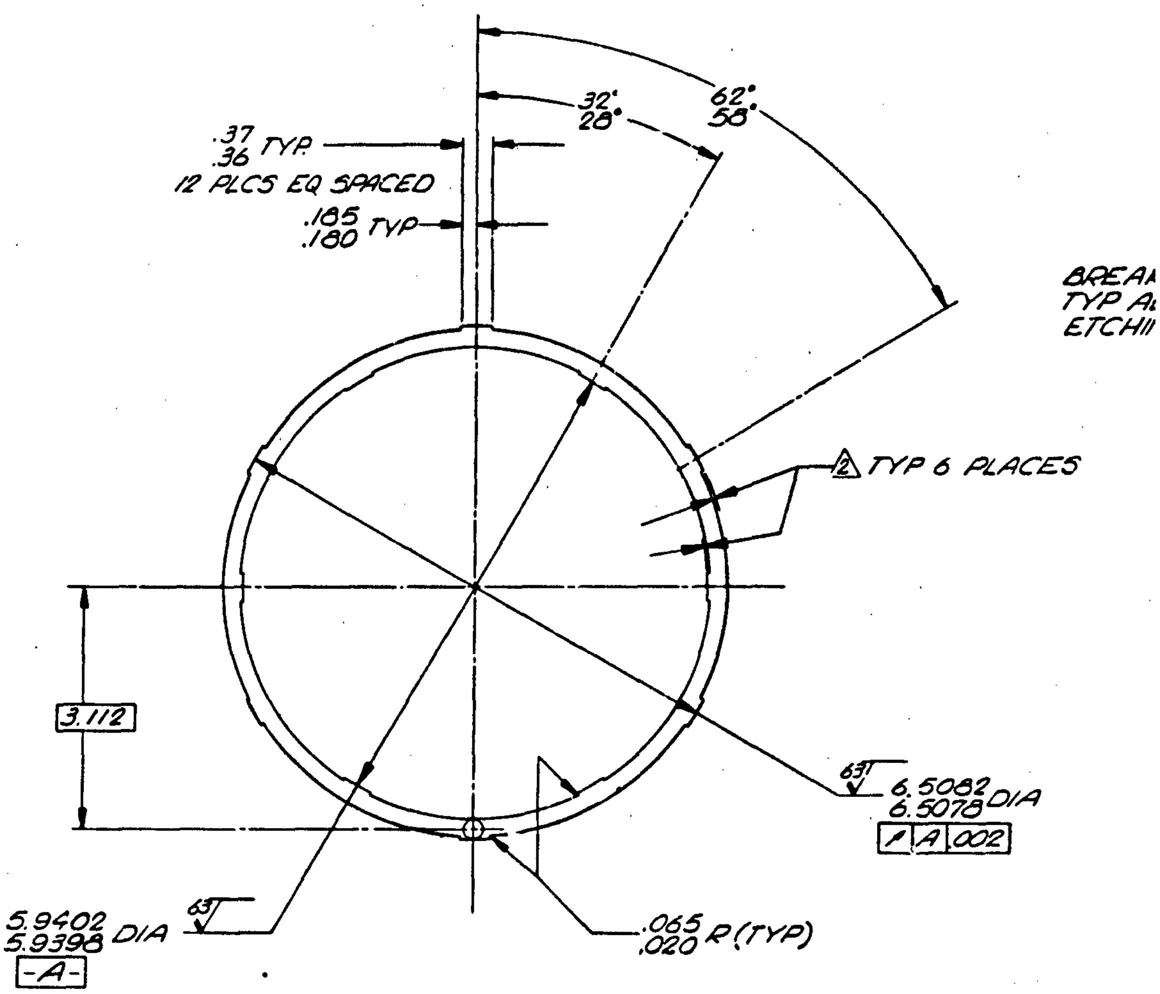
SIZE	CODE IDENT NO	DWG NO
C	70210	2047176

SCALE FULL WT 12LB SHEET 1 OF 1

T ASSY | USED ON
PLICATION

2

3-75/3-76



8. IRREGULAR SURFACE PROTRUSIONS OF .0004 MAX HEIGHT WITH .06 MAX SURFACE DIM ARE PERMISSIBLE ON ETCHED SURFACES BETWEEN PADS.
7. GLASS PEEN ALL OVER PER EMS 255, INTENSITY 7N2.
6. RUNOUT OF O.D. TO -A- DIA NEED NOT BE CHECKED WHILE PART IS IN FREE STATE
5. HEAT TREAT Rc 43-46 PER MIL-H-6875
4. MAGNETIC PARTICLE INSPECT PER MIL-I-686
3. CALCULATED RATE REF 264,550 LB/IN
2. CHEMICALLY ETCH OR MACHINE TO REMOVE .005-.007 PER SURFACE.
1. ALL SURFACES 125

NOTES: UNLESS OTHERWISE SPECIFIED

DWG NO 2047324

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

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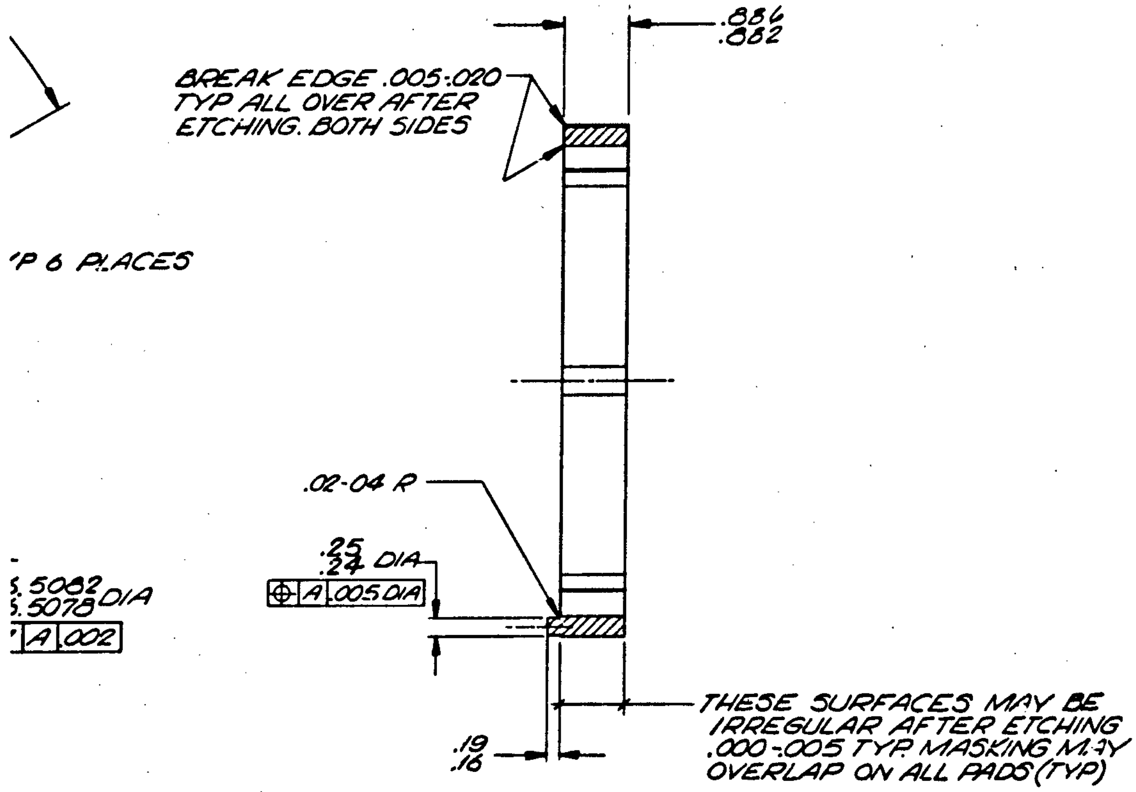
REV STATUS
SHEET



ROTRUSIONS OF
5 MAX SURFACE DIM
CHED SURFACES

PER EMS 255,

A NEED NOT BE
IN FREE STATE
? MIL-H-6875
ECT PER MIL-I-6868
4,550 LB/IN
ACHINE TO REMOVE

E SPECIFIED

PART NO 2047324-1

UNLESS OTHERWISE SPECIFIED: DWG CONTROL PER EGMS CB
STD INTERPRETATIONS PER PSS
IDENTIFICATION MARKING PER MC10 CL X-A

MATERIAL
6.50 O.D. TUBING
X .50 WALL
4340 STL. AMS 6415

FINISH

HEAT TREATMENT
5

2(-1)	2046870-1	
REQD	NEXT ASSY	USED ON
APPLICATION		

CONTRACT NO

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

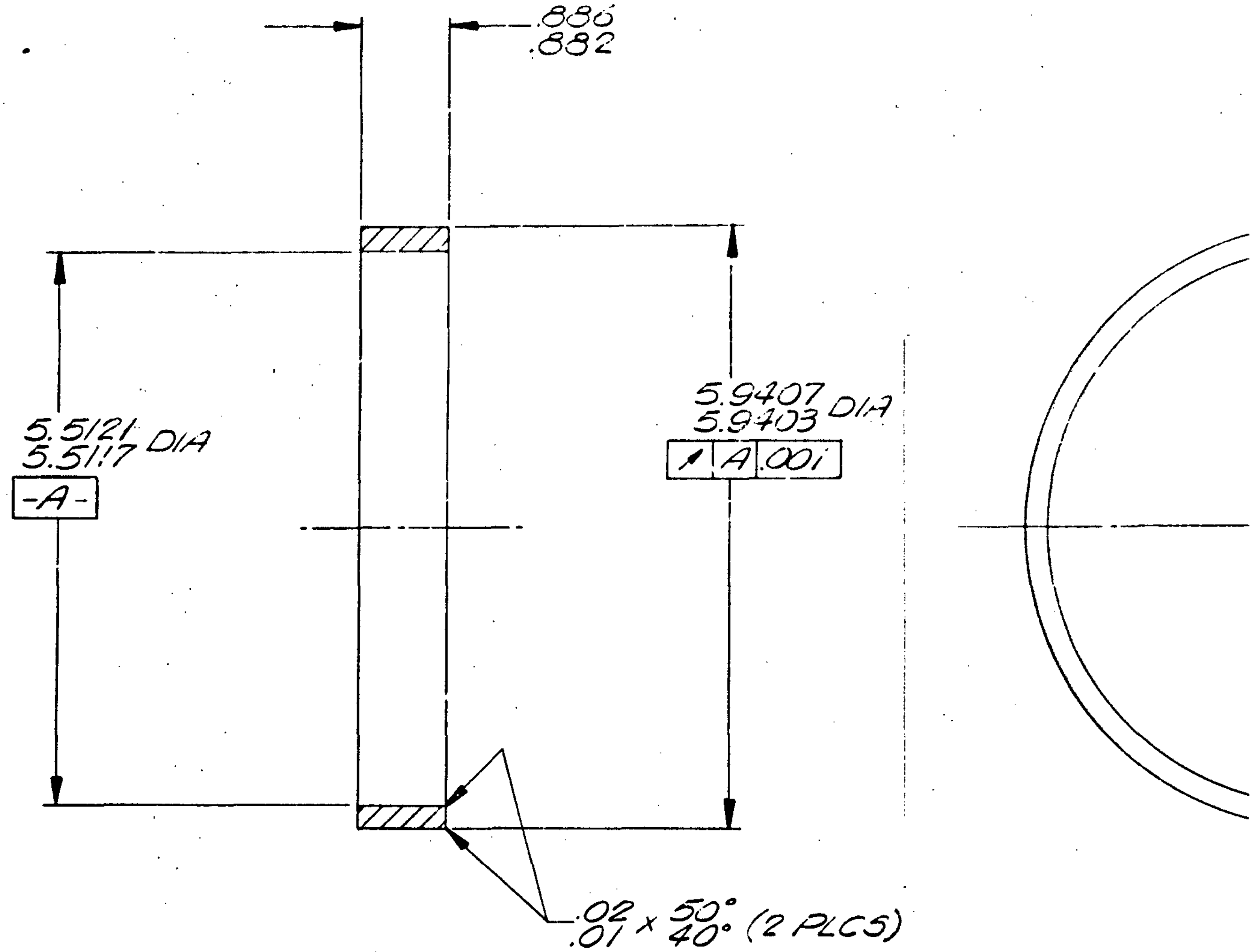
MOUNT, RESILIENT, BEARING

SIZE	CODE IDENT NO	DWG NO
D	70210	2047324

SCALE 1/1 SHEET 1 OF 1

3-77/3-78

2



PART NO. 2047325-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CL B
STD INTERPRETATIONS PER PIB5
IDENTIFICATION MARKING PER MC16

MATERIAL
6.00 DIA BAR
4340 STL.
MIL-S-5000

FINISH PROCESS

HEAT TREATMENT
2

2(-1)	2046870-1	
REQD	NEXT ASSY	USED ON
APPLICATION		

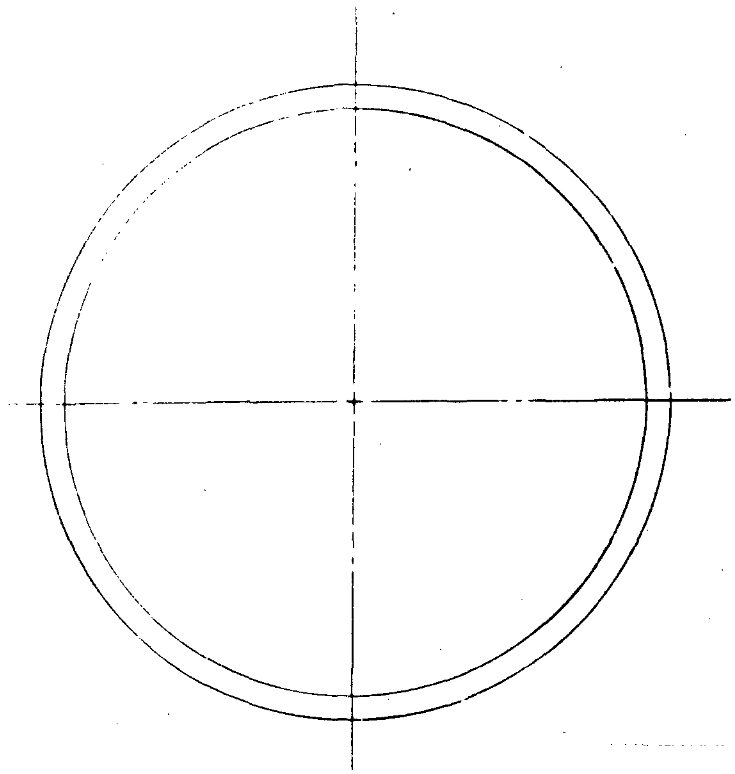
2. HEAT TREAT TO Rc 40-44 PER MIL-H-6875

1. ALL SURFACES 125

NOTES: UNLESS OTHERWISE SPECIFIED.

REVISIONS

ZONE	LTR	DESCRIPTON	DATE	APPROVED



9407 DIA
9403
[?] .001

(2 PLCS)

2047325

PART NO. 2047325-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CL B
STD INTERPRETATIONS PER PI85
IDENTIFICATION MARKING PER
MC16

MATERIAL
6.00 DIA BAR
4340 STL.
MIL-S-5000

FINISH PROCESS

HEAT TREATMENT
2

2046870-1	
NEXT ASSY	USED ON
APPLICATION	

CONTRACT NO

PREPARED BY Nick Rissig 8-3-79
CHKD 8-16-79
8-16-79
VALUE ENGR
MATL
STRESS
APVD W. H. Hasse 820104
DESIGN SUPERVISOR
PROJECT ENGINEER
GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

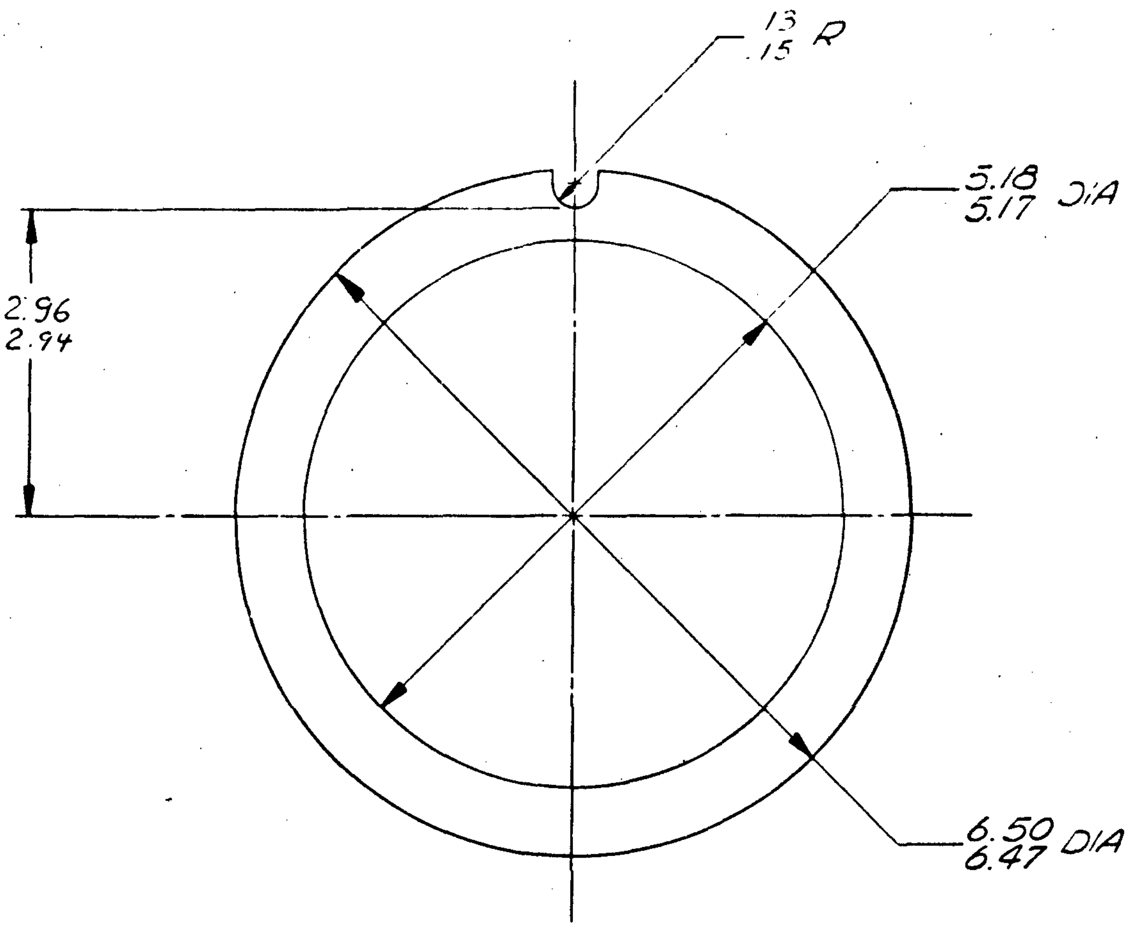
SPACER

SIZE	CODE IDENT NO	DWG NO
C	70210	2047325

SCALE 1/1 SHEET 1 OF 1

3-79/3-80

2



PART NO. 2047328-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC863 CL B
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER
MC16

MATERIAL
.010 STL STRIP
QQ-S-698
(1010 OR 1020)

FINISH PROCESS

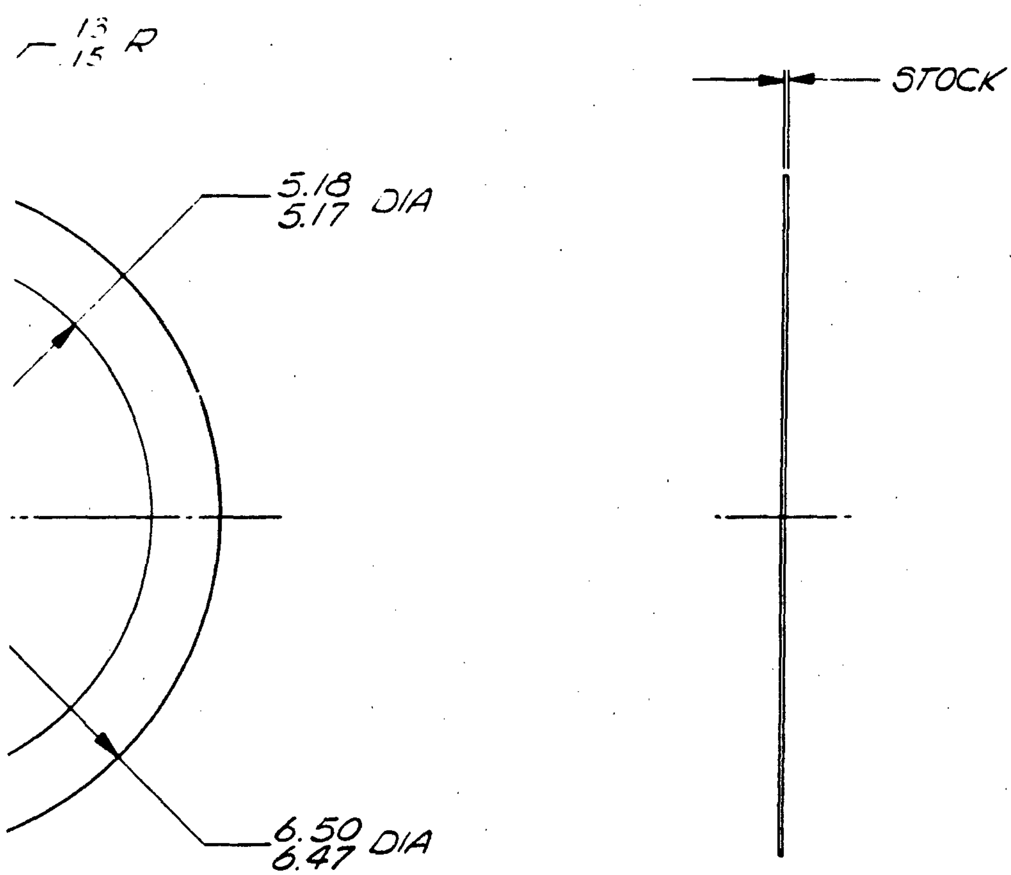
HEAT TREATMENT

AR (-1)	2046870-1	
REQD	NEXT ASSY	USED ON
APPLICATION		

PREPARE
CHK.
DESIGN
VALUE E
MATL
STRESS
APVD
DESIGN E
GOVERN

REVISIONS

ZONE	LTR	DESCRIPTON	DATE	APPROVED



2047328

PART NO. 2047328-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC053 CLB
STD INTERPRETATIONS PER PI86
IDENTIFICATION MARKING PER MC16

MATERIAL
.010 STL STRIP
QQ-S-698
(1010 OR 1020)

FINISH PROCESS

HEAT TREATMENT

CONTRACT NO

PREPARED BY Dick Passig 8-14-79
CHK. W. Kr... 8-14-79
DESIGN ... 8-14-79
VALUE ENGR.
MATL
STRESS
APVD W. H. House 8-20-69
DESIGN SUPERVISOR
PROJECT ENGINEER ... 1-12-82
GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

WASHER, SHIM

SIZE	CODE IDENT NO	DWG NO
C	70210	2047328

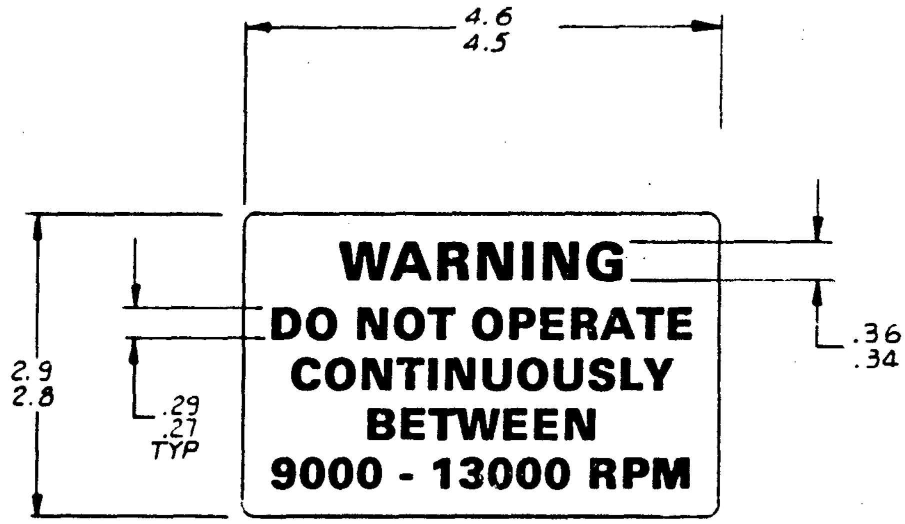
SCALE 1/1 | SHEET 1 OF 1

MOD	NEXT ASSY	USED ON
(-1)	2046870-1	

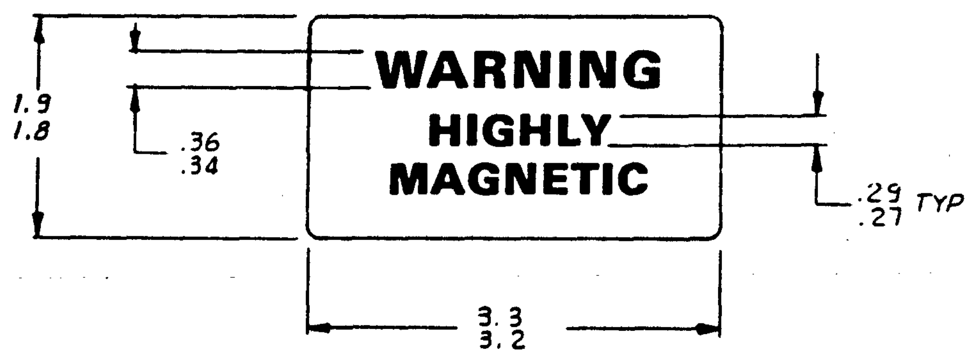
APPLICATION

2

3-81/3-82



(-1)



(-2)

PART NO. 2047329-

UNLESS OTHERWISE SPECIFIED:
BURP CONTROL PER SC663
STD INTERPRETATIONS PER P186
IDENTIFICATION MARKING PER MC16

MATERIAL ⚠1

FINISH PROCESS

HEAT TREATMENT

⚠1 MATERIAL: ADHESIVE BACKED METAL FOIL PER EMS 729, TYPE XIII-A
FINISH: DATA LETTERS TO BE RED ANODIZE ON NATURAL COLOR BACK GROUND.

NOTE UNLESS OTHERWISSE SPECIFIED.

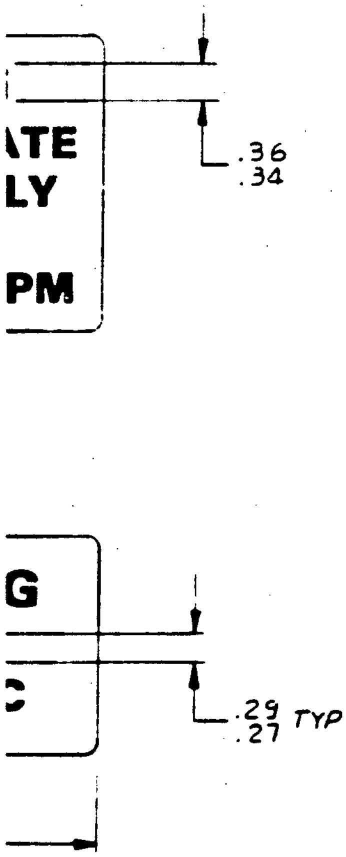
REQD	NEXT ASSY	USED ON
1-2	518405-1	518404-1
1-1	518405-1	518404-1

APPLICATION

REVISIONS

ZONE	LTR	DESCRIPTON	DATE	APPROVED
	A	SEE ENGINEERING ORDER	[illegible]	[illegible]

R
R



PART NO. 2047329-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC653 CLB
STD INTERPRETATIONS PER PI95
IDENTIFICATION MARKING PER MC16

MATERIAL

FINISH PROCESS

HEAT TREATMENT

518405-1	518404-1
518405-1	518404-1
NEXT ASSY	USED ON

APPLICATION

CONTRACT NO

PREPARED BY Dick Hassig 8-14-79
CHK 8-14-79
DESIGN 8-14-79
VALUE ENGR
MATL
STRESS
APVD
DESIGN SUPERVISOR
PROJECT ENGINEER
GOVERNMENT APVD

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

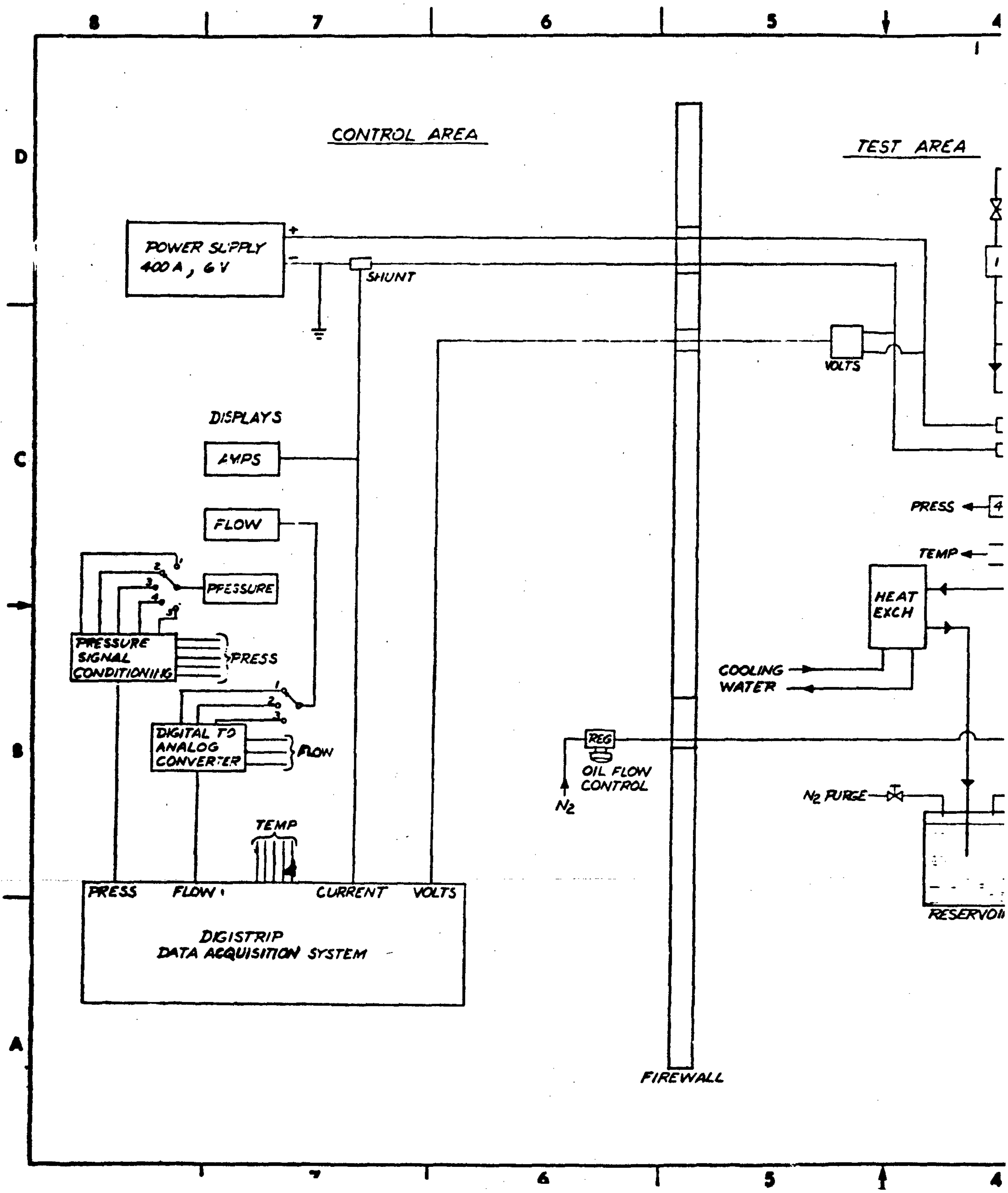
LABEL, WARNING

SIZE	CODE IDENT NO	DWG NO
C	70210	2047329

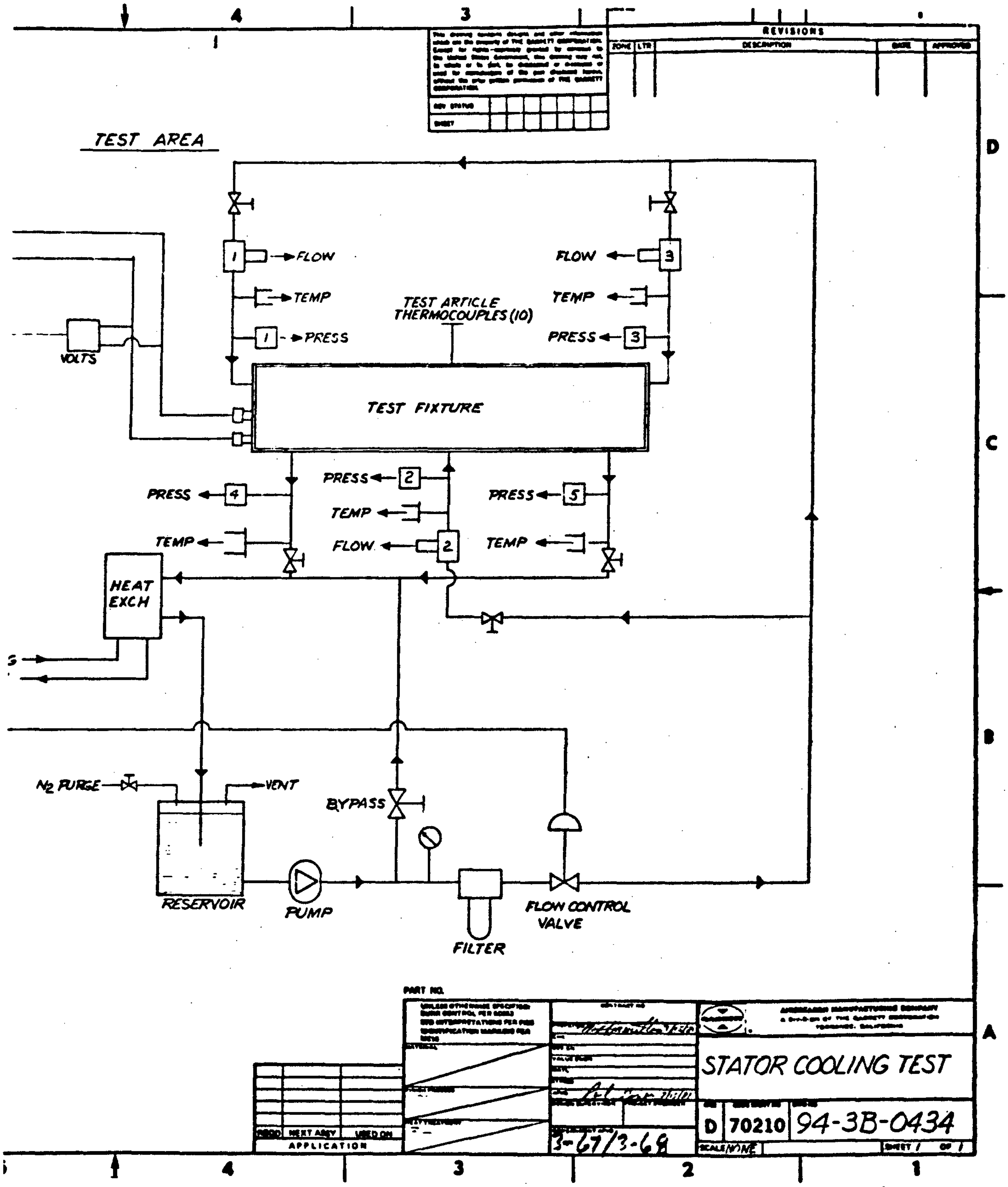
SCALE 1/1 SHEET 1 OF 1

2

3-83/3-84

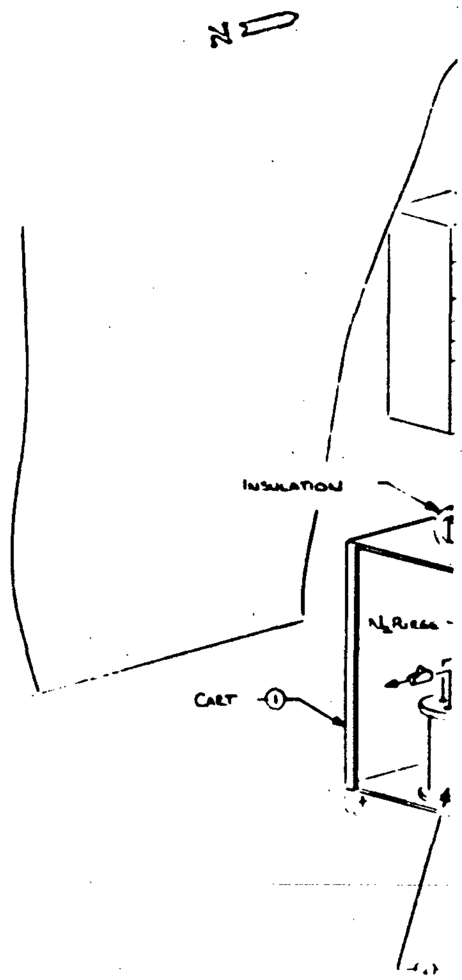


8
7
6
5
4
D
C
B
A
CONTROL AREA
TEST AREA
POWER SUPPLY
400 A, 6 V
+
-
SHUNT
VOLTS
DISPLAYS
AMPS
FLOW
PRESSURE
PRESSURE SIGNAL CONDITIONING
PRESS
DIGITAL TO ANALOG CONVERTER
FLOW
TEMP
PRESS
FLOW
CURRENT
VOLTS
DIGISTRIP
DATA ACQUISITION SYSTEM
REG
OIL FLOW CONTROL
N_2
FIREWALL
PRESS
TEMP
HEAT EXCH
COOLING WATER
N_2 PURGE

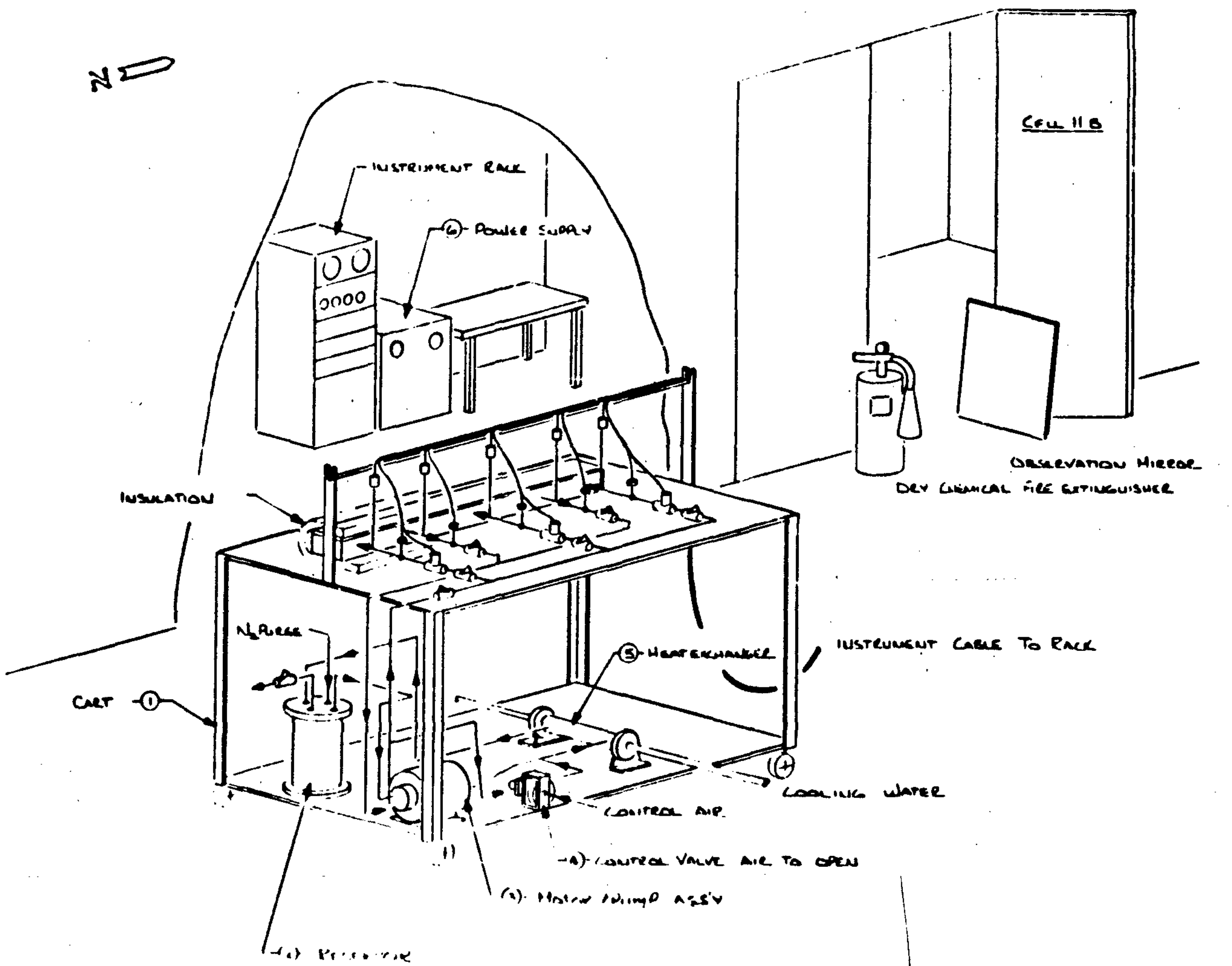

TEST AREA
FLOW
TEMP
PRESS
TEST ARTICLE THERMOCOUPLES (10)
FLOW
TEMP
PRESS
VOLTS
TEST FIXTURE
PRESS
TEMP
FLOW
PRESS
TEMP
PRESS
TEMP
HEAT EXCH
N2 PURGE
VENT
BYPASS
RESERVOIR
PUMP
FILTER
FLOW CONTROL VALVE
REVISIONS
PART NO.
APPLICATION
STATOR COOLING TEST
D 70210 94-3B-0434
SCALE NONE
3-67/3-68

2

SYMBOL	ITEM #	QTY	PART No.	DESCRIPTION
	1	1	LSC 17368-1	TEST CART
	2	1	LSC 17368-2	RESERVOIR
	3	1	TOOL No 1338020663	TUTHILL METERING PUMP
	4	1	58006-811 BS2	DAHL CONTROL VALVE
	5	1	AIES 731 MODIFIED	HEAT EXCHANGER
		3	SS-6JB	NUPRO SHUT OFF VALVE
		4	SS 6L	NUPRO METERING VALVE
		15		THERMO COUPLE
		3	LF6 or LF8	COX FLOW METER
		5	180-30	[illegible] PRESSURE TRANSDUCER
	N.S.	1		FILTER 10 MICRON
	N.S.	1	5159T-8TT-50	RELIEF VALVE 55 PSID CIRCLE SEAL
	6	1	SORENSON DCR 20-1000A	POWER SUPPLY 20V 1000A



NOTES:
1) TEST LOCATION NORTH EAST END TEST CELL 11B
2) TEST AREA TO BE ROPED OFF AS HAZARDOUS
3) TEST FIXTURE TO BE FULLY INSULATED TO PREVENT HEAT LOSS, 400°F MAX.
4) WERE N.S. IS INDICATED ITEM WAS NOT SHOWN ON ASSEMBLY FOR CLARITY



REVISIONS

PART NO.

S CRANDALL
12/15/81

STATOR COOLING TEST RIG
93-3 DEVELOPMENT

D 70210 LSK 17367

SCALE SHEET OF

APPLICATION

2 3-87/3-88

4. NO LOAD TEST PLAN

The no load test plan for the 5 MW generator (AiResarch Reoort 80-18822) is presented as Exhibit 4A. This report is submitted for approval.

EXHIBIT 4A

AIRESEARCH REPORT 82-18822
NO-LOAD TEST PLAN

CONTENTS

1. INTRODUCTION

1.1 SCOPE

No-load testing of the 5-Mw permanent magnet generator as described in this report will be an intermediate step in the development of an advanced nonsuperconducting synchronous generator for airborne applications. The rotor and stator/housing are presently being developed under two separate contracts with the Air Force Aeronautical Systems Division, Wright Patterson AFB, Ohio, for delivery in early 1982 and mid-1983, respectively.

This test plan is being prepared well in advance of hardware availability in order to effectively schedule the fabrication of special test equipment and to ensure ready utilization of the test facility.

A cutaway drawing of the generator to be tested is shown in Figure 1-1.

1.2 TEST FACILITY

The generator will undergo its no-load checkout at the AiResearch Torrance facility, Building 9A, Test Cell 31. After setup, approximately one week of testing will be required to perform the tests outlined in this plan.

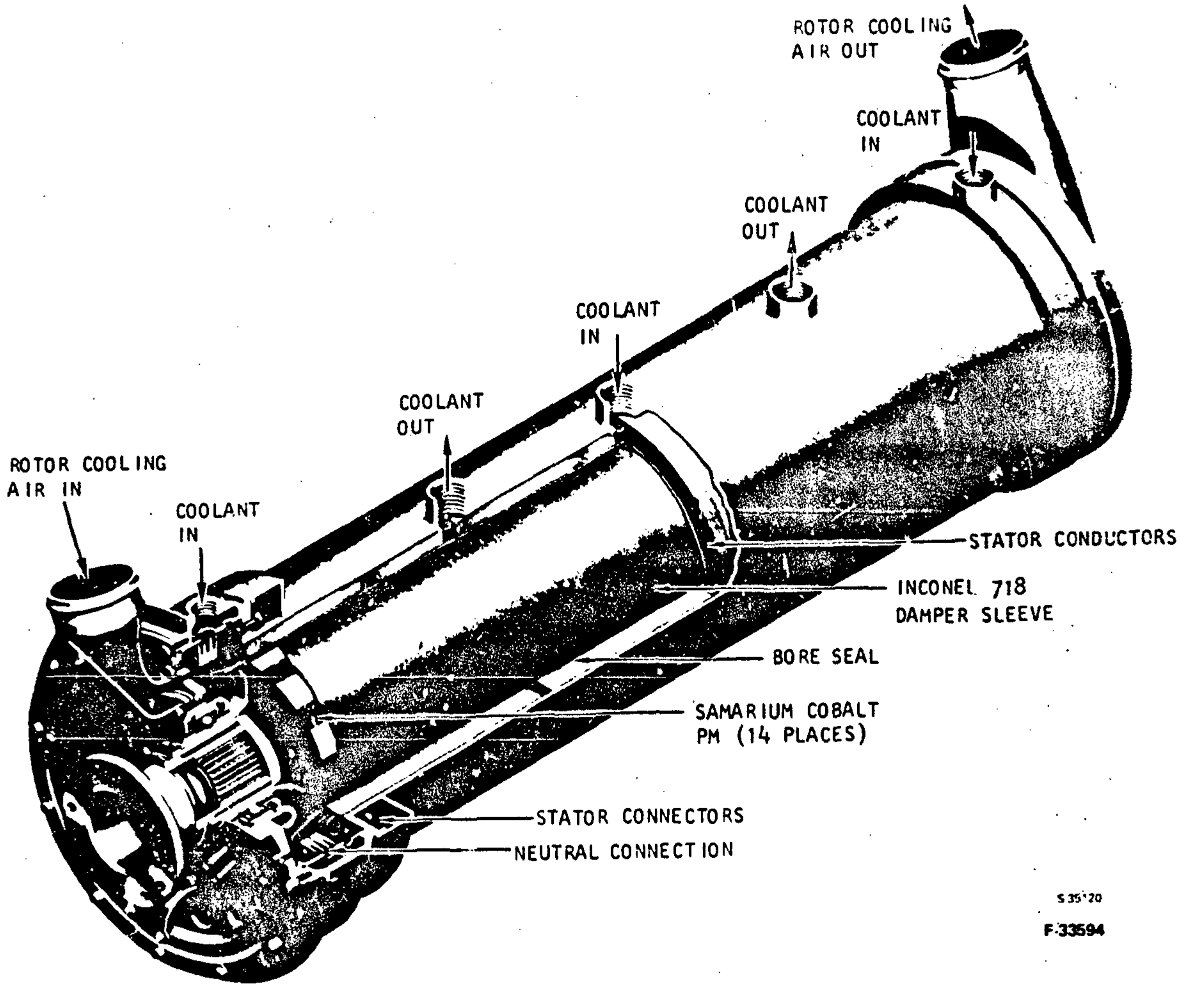


Figure 1-1. Complete 5-Mw Generator Design

2. GENERAL REQUIREMENTS

2.1 TEST SETUP

AiResearch Dwg. SK74954 details the 5-Mw generator as it will be configured for testing.

The overall test setup schematic is shown in AiResearch Dwg. S4-3B-0532.

Major design parameters for the generator are listed in Table 2-1.

TABLE 2-1

5-MW GENERATOR DESIGN PARAMETERS

Parameter	Value
Rating into 3-phase, full-wave bridge	1,046 vdc, 4,780 adc @ 18,000 rpm 648.3 v/phase (air gap), 3638 amp/phase
Current density, amp/in.^{2}	36,270
Stator temperature, °F	450
Rotor temperature, °F	200
Overall length, in.	43
Overall diameter, in.	16.25
Total weight, lb	500

2.2 COOLING REQUIREMENTS

2.2.1 Rotor

The permanent magnet rotor will be cooled by forced air generated by a test cell centrifical blower and measured with an orifice or venturi section. Cooling air will be discharged into the test cell (see Figure 2-1).

Operating parameters are the following:

Parameter	Requirement
Airflow	100 to 300 cfm
Air pressure	
Inlet	Ambient plus 0.5 psig
Outlet	Ambient
Air temperature	
Inlet	Ambient
Outlet	To 210°F

2.2.1.1 Blower Power Requirements

Power requirements for the blower are 230-460 vac, 3-phase, 60 Hz, 2 hp.

2.2.1.2 Instrumentation

Instrumentation requirements are as follows:

Parameter	Requirement
Flow	Measuring section inlet static pressure gage (1) and delta pressure gage (1)
Pressure	Unit inlet pressure transducer (1)
Temperature	
Inlet	Thermocouples (2)
Outlet	Thermocouples (2)

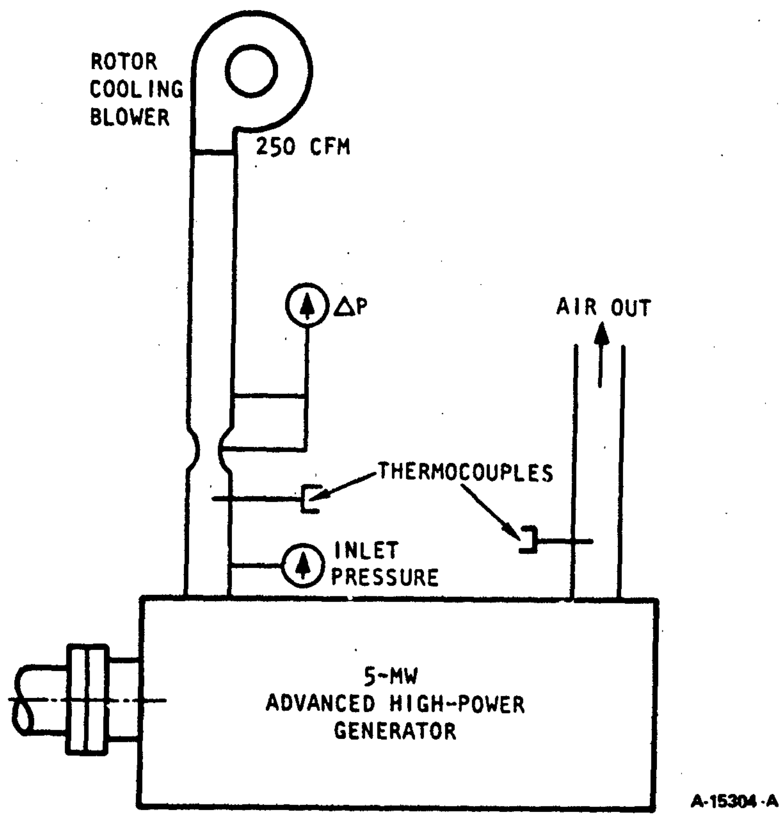


Figure 2-1. Rotor Cooling System

2.2.2 Stator

Stator conductors will be cooled by oil pumped through passages around the conductors. The cooling system (see Figure 2-2) will utilize a two-pump approach because of the requirement for a subatmospheric discharge pressure (7 psia) and a vented sump.

Operating parameters are shown in Table 2-2.

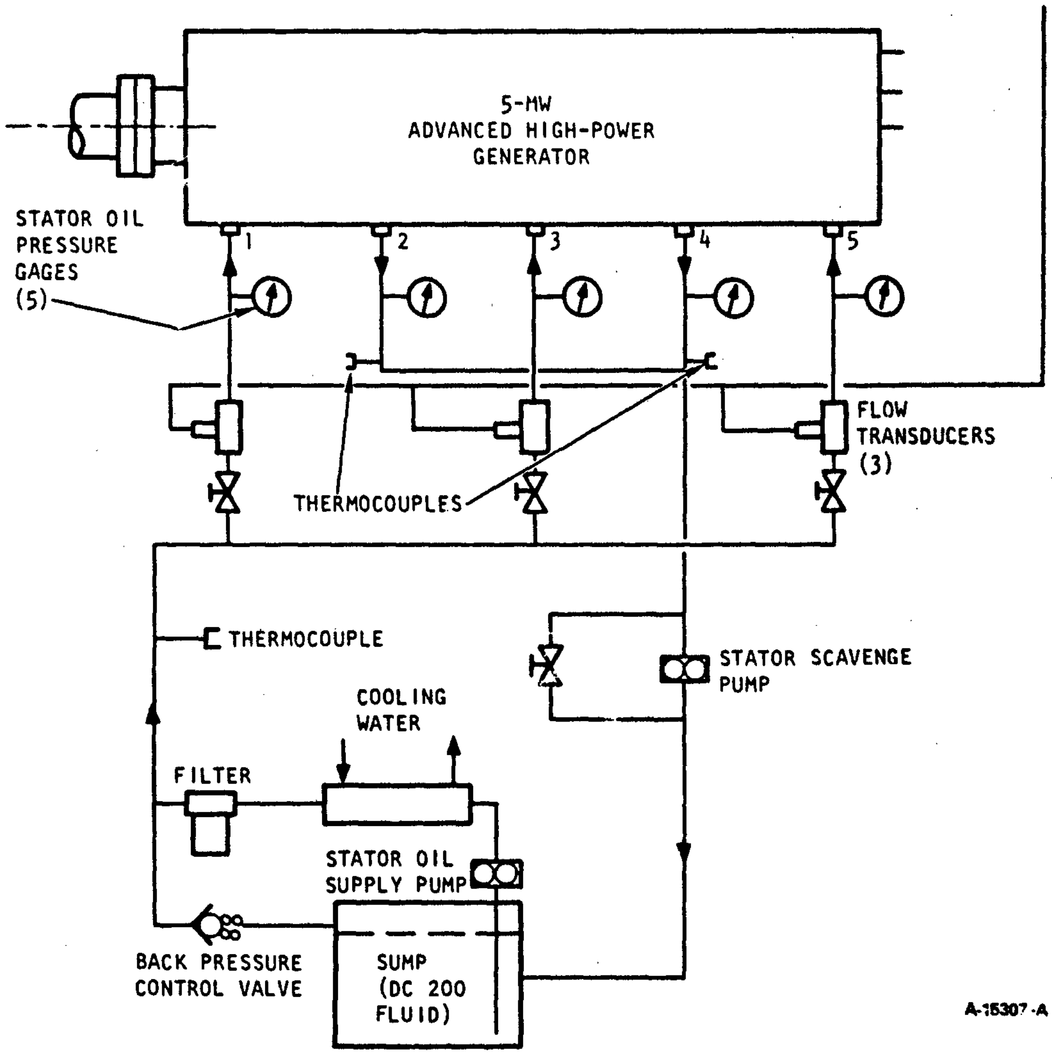


Figure 2-2. Stator Cooling System

2.2.2.1 Pump Power Requirements:

Power requirements for the pumps are as follows:

Parameter	Requirement
Supply	230 to 460 vac, 3-phase, 60 Hz, 1 hp
Scavenge	230 to 460 vac, 3-phase, 60 Hz, 3 hp

TABLE 2-2

STATOR OPERATING PARAMETERS

Parameter	Requirement
Oil	Dow Corning 200
Oil Flow	
Inlet No. 1, gpm	6.25
Inlet No. 3, gpm	12.5
Inlet No. 5, gpm	6.25
Total, gpm	25.0
Outlet No. 2, gpm	12.5
Outlet No. 4, gpm	12.5
Pressure	
Inlet, psia	19
Outlet, psia	7
Temperature	
Inlet, °F	120
Outlet, °F	To 250
Filtration, μ	25
Sump capacity, gal	50
Ultimate heat sink	Cooling tower water at TBD Btu/hr rate

2.2.2.2 Accessories

One level sight gage and five mechanical pressure gages are required.

2.2.2.3 Instrumentation

Instrumentation is required as follows:

Parameter	Requirement
Flow	Inlet transducers 0 to 6.25 gpm (2) 0 to 12.5 gpm (1)
Pressure	Inlet gages (psia) (3) Outlet gages (psia) (2)
Temperature	Inlet thermocouple (1) Outlet thermocouples (2)

2.2.3 Bearings

The rotor bearings will be cooled and lubricated by a system providing air-oil mist under pressure (see Figure 2-3).

Operating parameters are shown in Table 2-3.

2.2.3.1 Instrumentation

Instrumentation requirements are the following:

Parameter	Requirement
Pressure	Inlet gage (psia) (1)
Temperature	Inlet thermocouple (1) Outlet thermocouples (2)

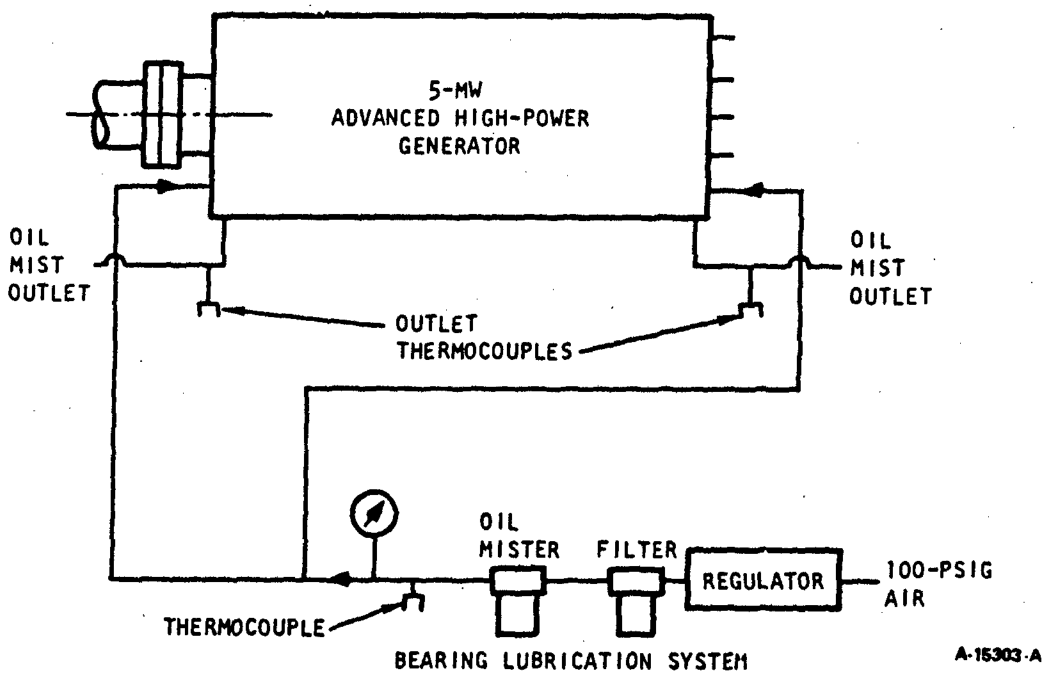


Figure 2-3. Bearing Cooling and Lubrication System

TABLE 2-3

BEARING OPERATING PARAMETERS

Parameter	Requirement
Oil	Mobile Jet II (MIL-L-23699)
Flow	
Air, lb/min	0.045
Oil	TBD
Pressure	
Inlet, psia	15.3
Outlet	Ambient
Temperature	
Inlet	Ambient
Outlet	TBD
Filtration,μ	10
Sump capacity, oz	10

2.3 MECHANICAL DRIVE SYSTEM REQUIREMENTS

The 5-mw advanced high-power generator will be supported by a heavy weldment stand. The stand in turn will be bolted to the test cell floor bed plate. In addition, the drive motor and gear box will also be bolted to the bed plate (see Figure 2-4).

The generator will be driven by an AiResearch manufactured standard light rail vehicle traction motor through a Vistar 7.7 to 1 step up gear box.

Drive system torque will be measured by a Lebow rotary transformer torque sensor with a maximum rating of 500 inch-pounds. The final drive system will consist of a specific pillow block assembly and flexibox two element disk/diaphragm coupling adapted to the generator shaft (see Figure 2-5).

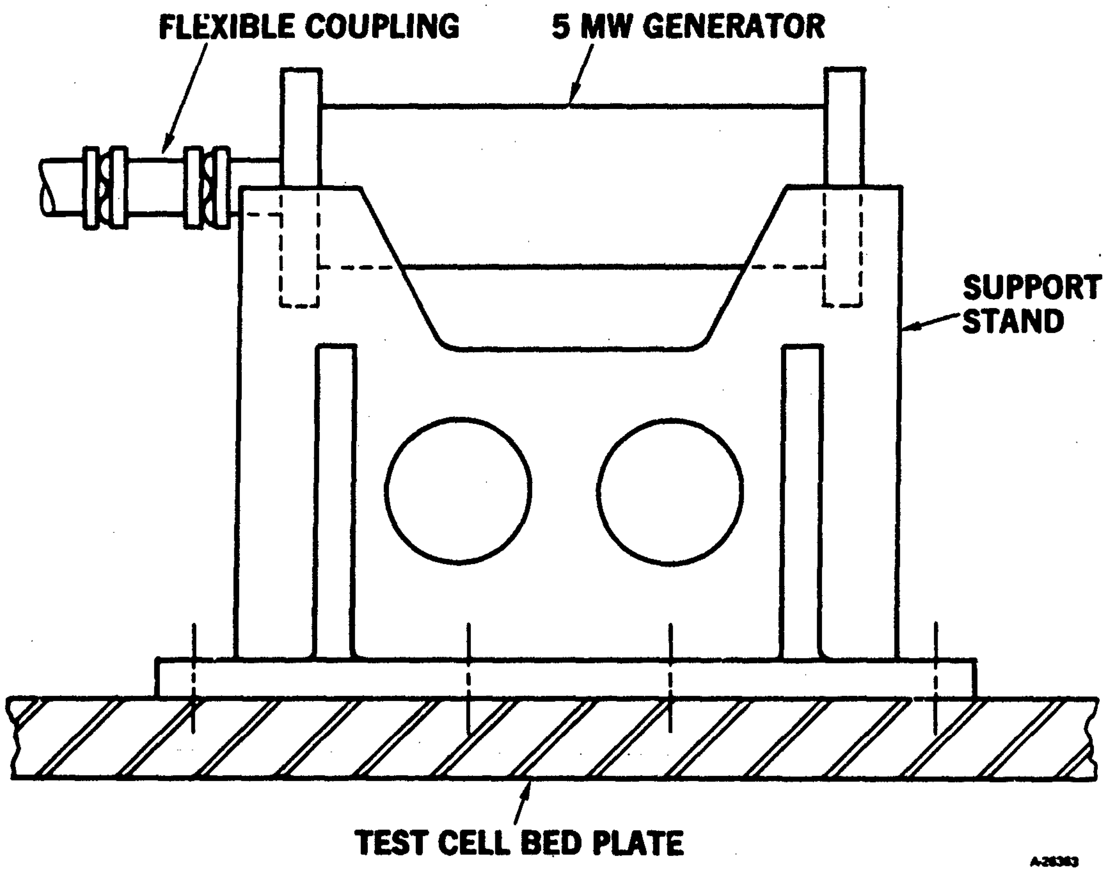


Figure 2-4. Generator Mounting

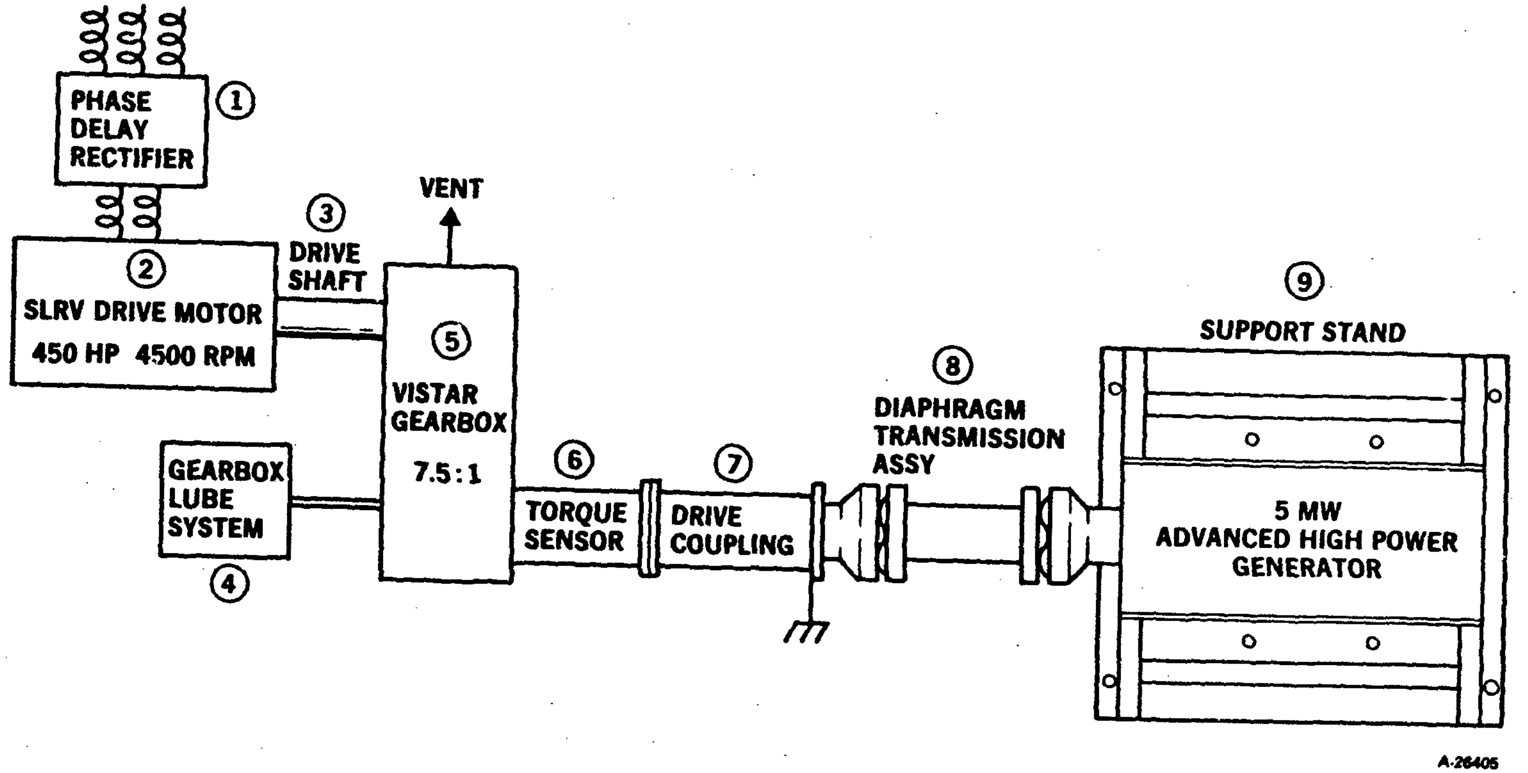


Figure 2-5. Mechanical Drive System (Top View)

2.3.1 Power Requirements

Drive horsepower and torque requirements are based on a no-load loss estimate of 71.2 kw at 18,000 rpm.

Generator input horsepower

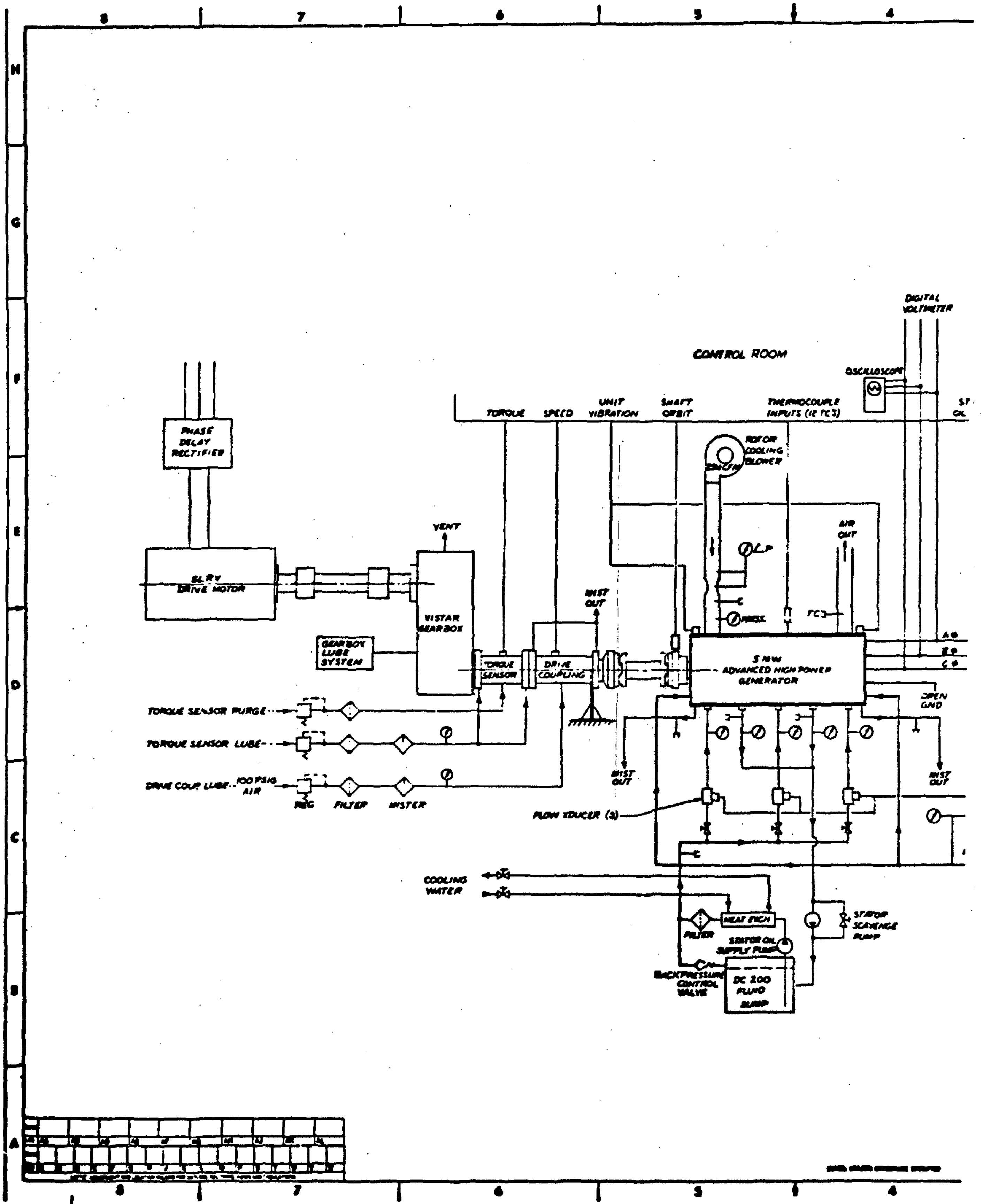
$$\frac{7.12 \times 10^4 \text{ w}}{746 \text{ w/hp}} = 95.4 \text{ hp}$$

Generator input torque

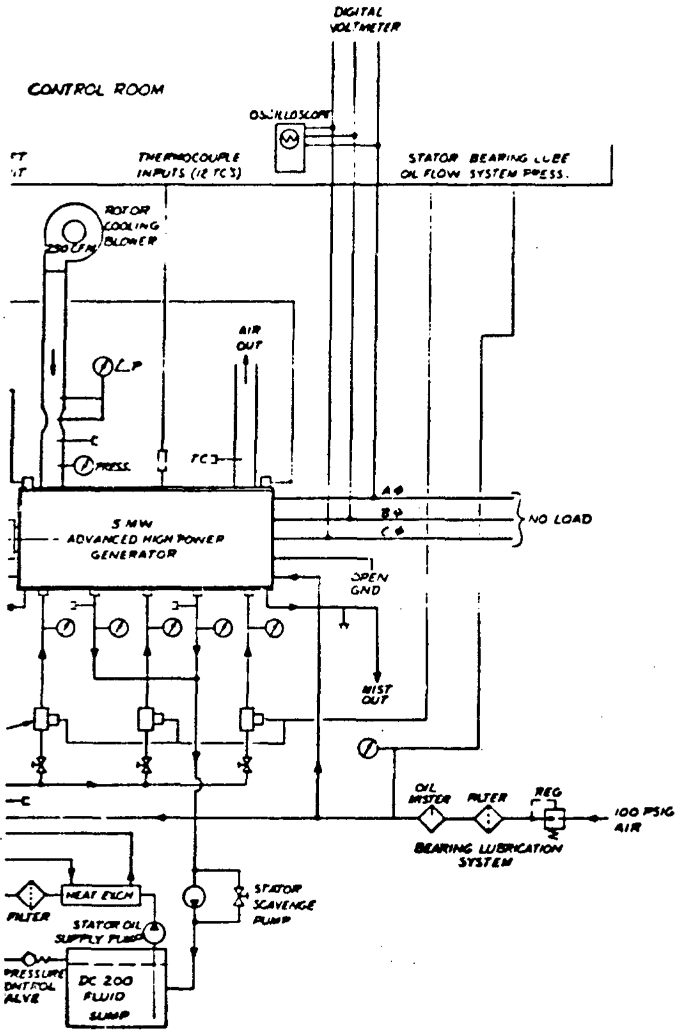
$$\frac{95.4 \text{ hp} \times 33{,}000 \text{ lb-ft/min./hp}}{2 \times 18{,}000 \text{ rpm}} = 27.8 \text{ ft-lb}$$

2.3.2 Drive System Components Required for Testing

Item No. from Figure 2-5	Requirement
1	Phase delay rectifier, supplies power and control for drive motor. Standard laboratory equipment
2	Drive motor, SLRV traction motor, 450 hp, 4500 rpm. Standard laboratory equipment.
3	Drive shaft assembly, floating shaft with two single flex gear couplings (Zurn). Standard laboratory equipment.
4	Lube system, gear box, MIL 23699 oil, 35 psig. Standard laboratory equipment.
5	Gear box, Vistar 7.75 to 1 step-up, 150 hp, Model 6513-3, S/N 664-16. Standard laboratory equipment.
6	Torque sensor, Lebow Model 1615K-500, 500 inch-pounds, 20,000 rpm, rotary transformer type, air/oil mist lubricated. Standard laboratory equipment.
7	Drive coupling assembly, dual angular contact bearings, air/oil mist lubricated. Provides speed signal and shear section protection, set point 900 in-lb. Special test equipment.
8	Transmission assembly, diaphragm. Manufacturer Flexibox, type Metastream, Model 3.5 T, spacer 5 inch. Rating 3.5 hp/100 rpm, maximum speed 25,500 rpm. Provides connection from drive coupling to generator and necessary flexibility to cope with residual misalignment.



CONTROL ROOM
DIGITAL VOLTMETER
OSCILLOSCOPE
TORQUE
SPEED
UNIT VIBRATION
SHAFT ORBIT
THERMOCOUPLE INPUTS (12 TC'S)
PHASE DELAY RECTIFIER
ROTOR COOLING BLOWER
VENT
AIR OUT
DRIVE MOTOR
VISTAR GEARBOX
GEARBOX LUBE SYSTEM
MIST OUT
PRESS.
TORQUE SENSOR
DRIVE COUPLING
5 MW ADVANCED HIGH POWER GENERATOR
OPEN GND
TORQUE SENSOR PURGE
TORQUE SENSOR LUBE
DRIVE COUP. LUBE
100 PSIG AIR
REG
FILTER
MISTER
FLOW XDUCER (3)
COOLING WATER
HEAT EXCH
FILTER
STATOR OIL SUPPLY PUMP
STATOR SCAVENGE PUMP
BACKPRESSURE CONTROL VALVE
DC 200 FLUID SUMP



SYSTEM TEST PLAN
5 MW GENERATOR
NO LOAD

E 70210 94-3B-0532

2

4-21/4-22

3. TEST INSTRUMENTATION

The instrumentation to be used for generator testing is listed in Table 3-1.

TABLE 3-1

TEST INSTRUMENTATION

System	Measurement	Sensor Type	Quantity
Drive Motor	Temperature, field	Thermocouple	1
	Voltage, arm.	Meter	1
	field	Meter	1
	Current, arm.	Meter	1
	field	Meter	1
Drive coupling	Speed	Monopole	1
	Temp. bearings	Thermocouple	2
	Oil mist pressure	Gage (psi)	1
	Vibration	Accelerometer	1
Gearbox	Temp. high speed shaft bearings	Thermocouple	2
	Oil pressure	Gage (psi)	1
	Vibration	Accelerometer	1
Torque Sensor	Torque, inch-lb.	AiResearch special test equipment, optical phase shift type, or Lebow 1615K-500.	1
	Temp, bearings	Thermocouple	2
	Oil mist pressure	Gage (psi)	1
	Purge pressure	Gage (psi)	1
Rotor	Vibration, vertical	Accelerometer	2
	horizontal	Accelerometer	2
	Temperature	Temperature sensitive paint	

Rotor Cooling	Temp., air inlet air outlet	Thermocouple Thermocouple	1 1
	Pressure, air inlet	Gage	1
	Air Flow, lb/min.	Orifice	1
Stator	Conductor Temp.	Thermocouple	44
Stator Cooling	Temp., oil inlet oil outlet	Thermocouple Thermocouple	1 2
	Pressures: oil inlet 0-25 psia oil outlet 0-25 psia	 Gage Gage	 3 2
	Oil flow 0-15 gpm	Turbine	3
Bearings, Generator	Temperature: oil mist inlet oil mist outlet	 Thermocouple Thermocouple	 1 2
	Press., oil mist inlet	Gage	1
Electrical	Voltage	Digital voltmeter	1
	Wave form	Oscilloscope	1

4. NO LOAD TEST PROCEDURE

The following must be verified before testing begins:

SLRV drive motor cooling air on
Gearbox oil system on, 30-35 psig
Torque sensor purge on, 3 psig
Torque sensor bearing mist on, 10 psig
Drive coupling bearing mist on, 10 psig
Unit rotor air flow on, 250 scfm
Unit rotor bearing mist on, 10 psig
Cooling water on
Stator scavenge pump on
Stator supply pump on, set required flows in 3 circuits

After all the lubrication and cooling systems have been thoroughly checked and the required coolant and air flows have been demonstrated, the alternator may be tested at speed according to the procedures outlined below.

This series of tests will determine the no load voltage versus speed characteristics of the alternator and the stator cooling capabilities with iron losses only.

The losses under no load and rated load were predicted by mathematical model Bigmag to be as follows:

WATTS x 1000 at 18,000 rpm

Loss Type	No-Load	Rated Load
Iron	58.6	41.0
Copper	0	136.0
Stray	0	45.3
Windage	12.0	12.0
Pole Head	0.5	1.0
Rotor Damper	0	7.7
Total Losses	71.1	243.0

A considerable amount of power (71.0kw) must be dissipated by the stator cooling system during no-load operation even though no output power is being used.

The test is begun by running the alternator at 1000 rpm and then increasing the speed to 18,000 rpm in 1000 rpm increments. Discrepencies in any of the test variables must be resolved before moving to the next higher speed. The test variables that must be recorded are shown in the sample lab data sheets in Figures 4-1 and 4-2. The actual gathering of data will be done with a data logger such as the Kaye Digistrip II or III. The acceptable range of the variables during the testing is shown in Table 4.1. The data logger will be programmed to register an alarm if any of the minimum or maximum values are sensed. Input power is a variable that is calculated according to the following equation.

$$\text{Input Power(kw)} = \frac{\text{Shaft Torque (lb.-ft.)} \times 2 \times \pi \times \text{rpm} \times 0.7456}{33{,}000} \frac{\text{kw}}{\text{hp}}$$

This calculation can be performed internally by the data logger and printed out along with the other variables.

FORM #1880A
AiResearch Mfr

LAB DATA SHEET

EWO ______ DATE ______ TEST PURPOSE ______

P/N ______ BAROM ______

S/N ______ TEMP ______ TEST PERS. ______

	Time	Speed rpm x 1000	V_{L-N}			Coolant Inlet Pressure (psi)			Coolant Flow (gpm)			Coolant Inlet Temp. °F			Coolant Outlet T. °F		
			A-B	B-C	A-C	P_1	P_2	P_3	F_1	F_2	F_3	T_{CI_1}	T_{CI_2}	T_{CI_3}	T_{CO_1}	T_{CO_2}	
NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	REMARKS
1																	
2																	
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Figure 4-1. Lab Data Sheet (Page 1 of 2)

LAB DATA SHEET

Page 2 of 2

EWO ________ DATE ________ TEST PURPOSE ________

P/N ________ BAROM ________ ________

S/N ________ TEMP ________ TEST PERS. ________

	Bearing Temp. °F		Bearing lube Press. psi		Stator Back Iron Temperature °F				Rotor Inlet Air Press. psi	Shaft Torque ft-lb	Input Pwr. (kw) Calc					
	FT	REAR	FT	REAR	T_{S_1}	T_{S_2}	T_{S_3}	T_{S_n}								
NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	REMARKS
1																
2																
3																
4																
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Figure 4-2. Lab Data Sheet (Page 2 of 2)

TABLE 4-1

OUTPUT VARIABLE RANGES

Variable	Range		
	Min	Max	Units
Speed	0	18,000	rpm
Volts, line to neutral	0	588	volts
Coolant inlet pressure	5	20	psi
Coolant flow	.1	.2	gpm
Coolant inlet temperature	75	250	°F
Coolant outlet temperature	75	400	°F
Bearing temperature	75	300	°F
Bearing lube system pressure	10	20	°F
Stator back iron temperature	75	400	°F
Roto, inlet air pressure	20	30	psi
Shaft torque	0	30	ft.-lbs.
Input power	0	71	kw

5. SYSTEM SAFETY/HAZARD ANALYSIS

A preliminary hazard analysis has been completed for the advanced high-power generator test. All hazards found appeared to be adequately controlled except that of dropping the generator during installation. Extreme care should be exercised in lifting the generator since no dedicated attachment points have been provided. This document supplements AiResearch Report 80-17402.

5.1 ANALYSIS

The preliminary hazard analysis for the advanced high-power generator test is contained in Table 5-1. Column 1 of the table lists the hazardous conditions that are or may be present during testing or installation of the generator. The possible causes of these conditions are listed in Column 2. The third column lists the possible effects of the hazardous condition. Hazard levels were assigned to the hazardous condition effects per MIL-STD-882A categorized as follows:

Hazard Category Classification	Description
I (Catastrophic)	May cause death of personnel or loss of generator or test facility (unrepairable).
II (Critical)	May cause severe injury to personnel or major damage to generator or to test facility (repairable).
III (Marginal)	May cause minor injury to personnel or minor generator or test facility damage.
IV (Negligible)	Will not result in injury to personnel or damage to the generator or to the test facility.

These hazard levels are applied in the fourth column of Table 5-1. The last column lists recommended corrective action and describes the protective features of the generator and test facility.

5.2 CONCLUSIONS AND RECOMMENDATIONS

There are four Category II hazards, four Category III hazards, and one Category IV hazard associated with the installation and testing of the advanced high-power generator. Adequate protection has been provided against all hazards except those associated with lifting the generator. Special care must be taken to prevent damage to the generator or injury to personnel when the unit is moved.

TABLE 5-1

PRELIMINARY HAZARD ANALYSIS

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DISCUSSION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
Bearing Seizure	1. Contamination of bearing. 2. Foreign material between rotor and housing. 3. Loss of bearing lubrication.	1. Large inertia loads leading to possible fracture of fixture mounts and freed rotor/housing assembly.	II	1. Bearings are ABEC 7 quality with oil spray lubrication. 2. Personnel will not be permitted in the test chamber during testing. 3. Test fixture will be designed to hold the generator in the event of rotor lock up at maximum speed.
Large Mass of Generator	1. Absence of lifting provisions allows generator to be dropped during transportation or installation.	1. Possible fracture of generator parts. 2. Possible injury to personnel moving the generator.	III	Appropriate provisions should be made to enable safe movement of the generator, e.g., lifting eyelets.
Rotor Overspeed	1. Test equipment malfunction	1. Possible rotor burst, releasing fragments of steel into the test chamber.	II	1. Shaft speed is instrumented. Test fixture contains provisions for emergency shutdown in case of overspeed. 2. Shields are provided to contain fragments to the test facility. 3. No personnel will be permitted in facility during testing.
Fire	1. Bearing overheat from contamination or too much oil during operation. 2. DC 200 cooling oil igniter (flash) point 175°F, Autoignition Temp. 806°F). a) From overheat. b) From electrical spark.	1. Possible injury to personnel or equipment damage.	III	1. Oil/air mister should filter oil. 2. Facility is equipped with fire detection and 4 tons of 300 psig CO_2 for total flooding extinguishment. 3. Inlet and outlet oil/air mixture pressure and temperature will be monitored and alarm will sound if temperature is excessive or pressure is too low. 4. Outlet cooling oil temperature will be monitored and alarm will sound if temperature becomes excessive.

TABLE 5-1 (Continued)

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DISCUSSION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
High Voltage	1. Exposed terminals may come into contact with personnel or equipment.	1. Possible injury to personnel or equipment damage.	IV	1. Personnel will not be in vicinity when test is in progress. 2. An insulating cover will be provided.
Static Electricity	1. Buildup during test due to improper grounding.	1. May cause personnel injury, equipment damage or initiate a fire.	III	1. Generator will be grounded during test by bolting to the test fixture.
Excessive Vibration	1. Bearing failure. 2. Bearing support failure. 3. Rotor imbalance due to internal fracture.	1. Damage to generator and test equipment; may lead to fatigue failure of generator parts.	II	1. Test fixture contains provisions for quick shutdown in case of excessive vibration. 2. Bearings are resilient-mounted. 3. Structural integrity has been verified by rotor test and stress analysis.
Excessive Torque at Shaft	1. Malfunction of test equipment. 2. Bearing failure. 3. Rotor becomes locked with stator.	1. Possible overstress of generator parts; e.g., windings, shaft or bearing.	II	1. Torque sensor is provided on the input shaft; alarm will sound if torque is excessive.
Short Circuit	1. Damaged winding. 2. Misconnection of windings.	1. Loss of load. 2. Overheated windings. 3. Fire.	III	1. Phase balance is sensed and there will be quick shutdown if unbalance is excessive.

5. LOAD TEST PLAN

The test plan for the 5 MW generator (AiResearch Report 81-17964) is presented as Exhibit 5A. This report was approved in a previous submittal.

EXHIBIT 5A

AIRESEARCH REPORT 81-17964
TEST PLAN

FOREWORD

This test plan describes the procedure for testing a 5-Mw permanent magnet generator currently being built under the Advanced High Power Generator program, Contract F33615-76-C-2168, sponsored by the Power Systems Branch, Aerospace Power Division, of the Aeropropulsion Laboratory at Wright-Patterson Air Force Base.

At Wright-Patterson, the program is under the technical direction of Paul R. Bertheaud. At AiResearch, Fred B. McCarty is principal investigator, Frank E. Echolds is project engineer, and Andrew R. Druzsba is program manager. Special acknowledgement is given to Paul Gassen, AiResearch test engineer.

CONTENTS

1. INTRODUCTION

1.1 SCOPE

Full-load testing of the 5-Mw permanent magnet generator as described in this report will be the final step in the development of an advanced nonsuperconducting synchronous generator for airborne applications. The rotor and stator/housing are presently being developed under two separate contracts with the Air Force Aeronautical Systems Division, Wright Patterson AFB, Ohio, for delivery in late 1981 and mid-1983, respectively.

This test plan is being prepared well in advance of hardware availability in order to effectively schedule the fabrication of special test equipment and to ensure ready utilization of the test facility.

A cutaway drawing of the generator to be tested is shown in Figure 1-1.

1.2 TEST FACILITY

The generator will be delivered to the Compressor Research Facility (CRF), Wright Patterson AFB, for testing after a no-load checkout at AiResearch. Generator test support requirements have already been coordinated with CRF personnel. After setup, approximately three weeks of testing will be required to perform the tests outlined in this plan.

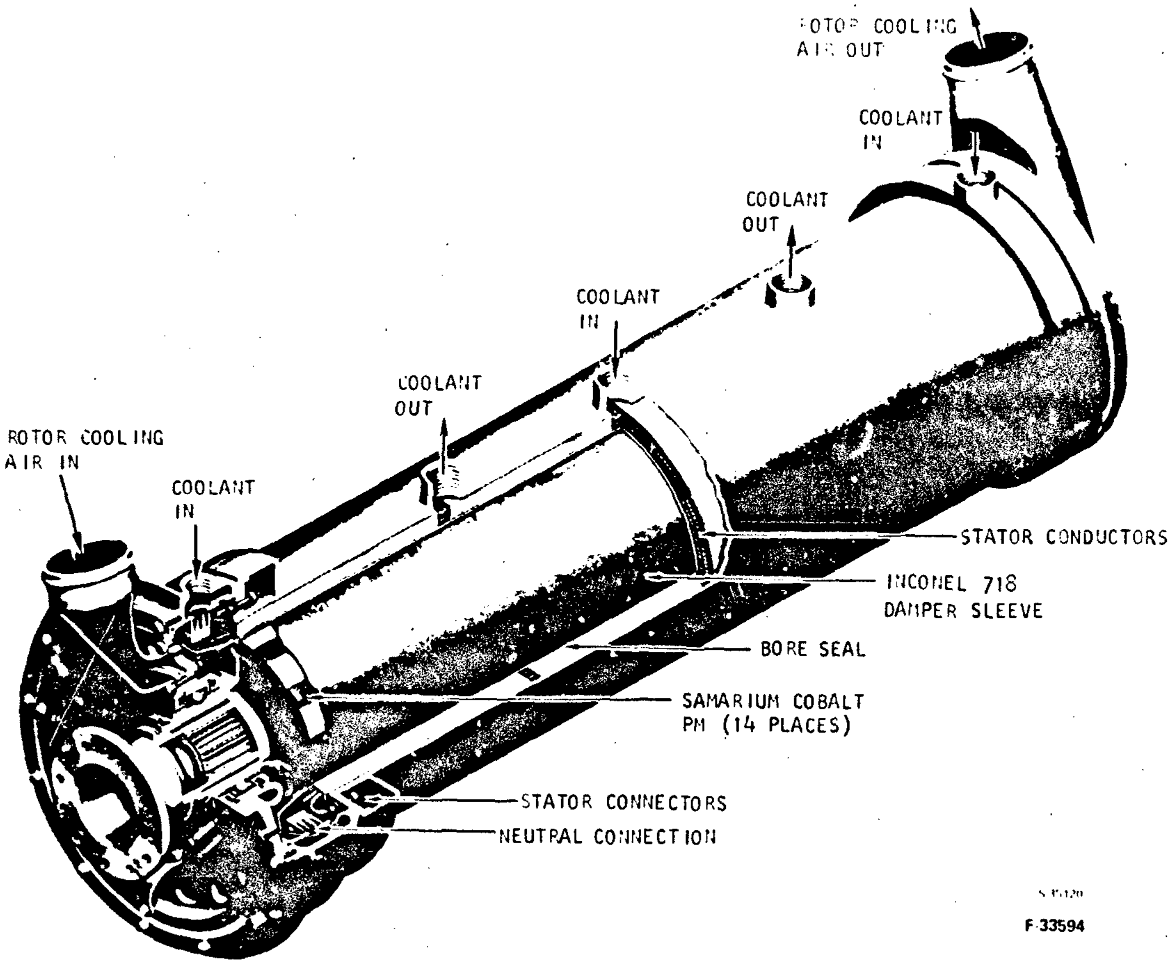


Figure 1-1. Complete 5-Mw Generator Design

2. GENERAL REQUIREMENTS

2.1 TEST SETUP

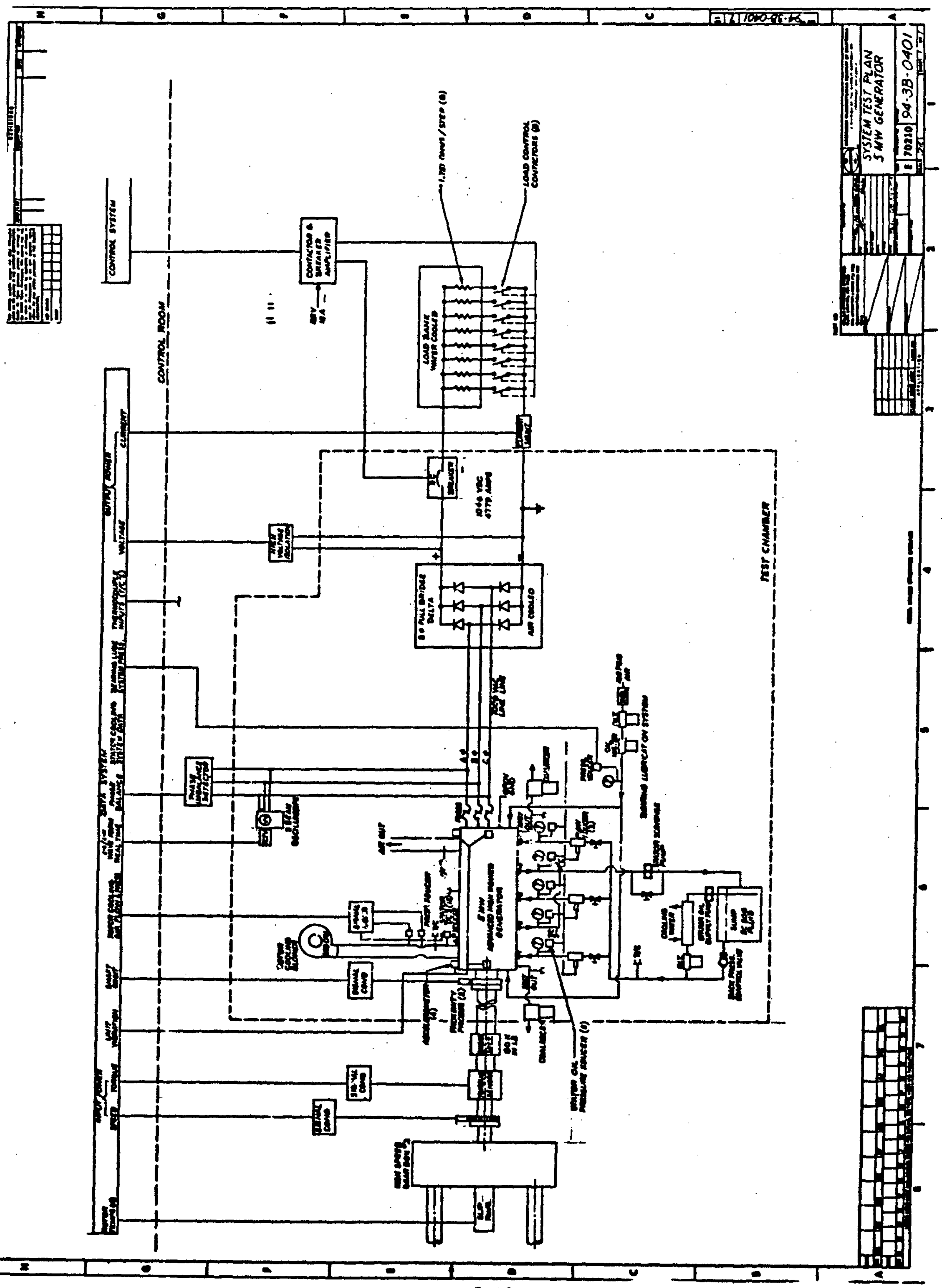
The overall test setup schematic is shown in AiResearch Dwg. 94-3B-0401.

Major design parameters for the generator are listed in Table 2-1.

TABLE 2-1

5-MW GENERATOR DESIGN PARAMETERS

Parameter	Value
Rating into 3-phase, full-wave bridge	1,046 vdc, 4,780 adc @ 18,000 rpm 648.3 v/phase (air gap), 3638 amp/phase
Current density, amp/in.^{2}	36,270
Stator temperature, °F	450
Rotor temperature, °F	200
Overall length, in.	43
Overall diameter, in.	16.25
Total weight, lb	500


SYSTEM TEST PLAN
5 MW GENERATOR
94-3B-0401
CONTROL ROOM
TEST CHAMBER
CONTROL SYSTEM
LOAD BANK WATER COOLED
AIR COOLED

2.2 COOLING REQUIREMENTS

2.2.1 Rotor

The permanent magnet rotor will be cooled by forced air generated by a test chamber centrifical blower and measured with an orifice or venturi section. Cooling air will be discharged into the test chamber (see Figure 2-1).

Operating parameters are the following:

Parameter	Requirement
Airflow	100 to 300 cfm
Air pressure	
Inlet	Ambient plus 0.5 psig
Outlet	Ambient
Air temperature	
Inlet	Ambient
Outlet	To 210°F

2.2.1.1 Blower Power Requirements

Power requirements for the blower are 230-460 vac, 3-phase, 60 Hz, 2 hp.

2.2.1.2 Instrumentation

Instrumentation requirements are as follows:

Parameter	Requirement
Flow	Measuring section inlet static pressure transducer (1) and delta pressure transducer (1)
Pressure	Unit inlet pressure transducer (1)
Temperature	
Inlet	Thermocouples (2)
Outlet	Thermocouples (2)

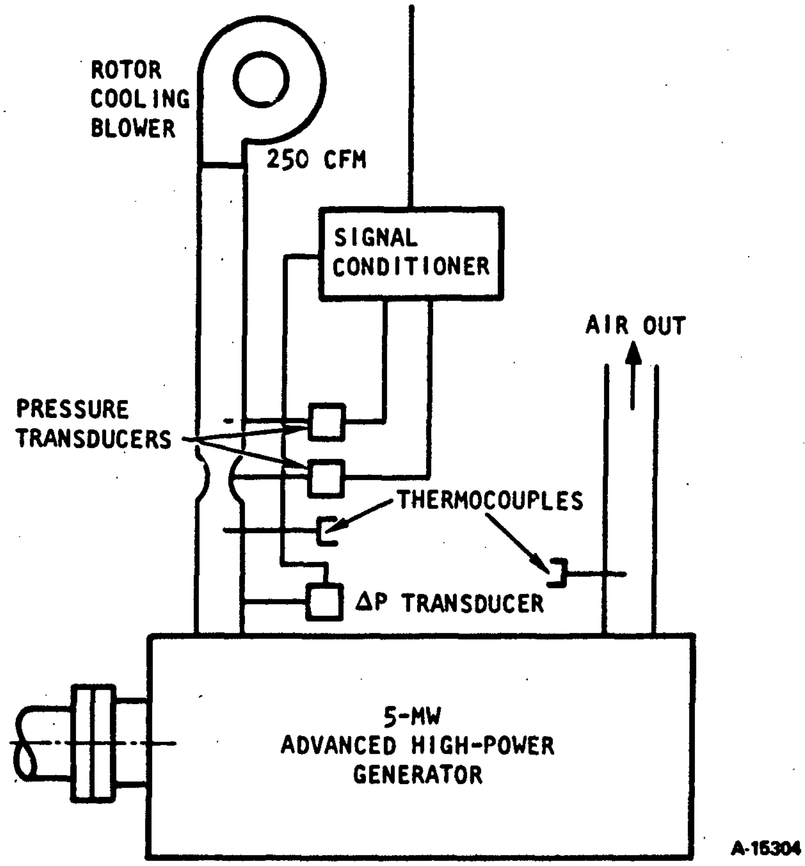


Figure 2-1. Rotor Cooling System

2.2.1.3 Alarms

Alarm requirements are the following:

Parameter	Requirement
High discharge temperature	1
Low airflow	1

2.2.2 Stator

Stator conductors will be cooled by oil pumped through passages around the conductors. The cooling system (see Figure 2-2) will utilize a two-pump approach because of the requirement for a subatmospheric discharge pressure (7 psia) and a vented sump.

Operating parameters are shown in Table 2-2.

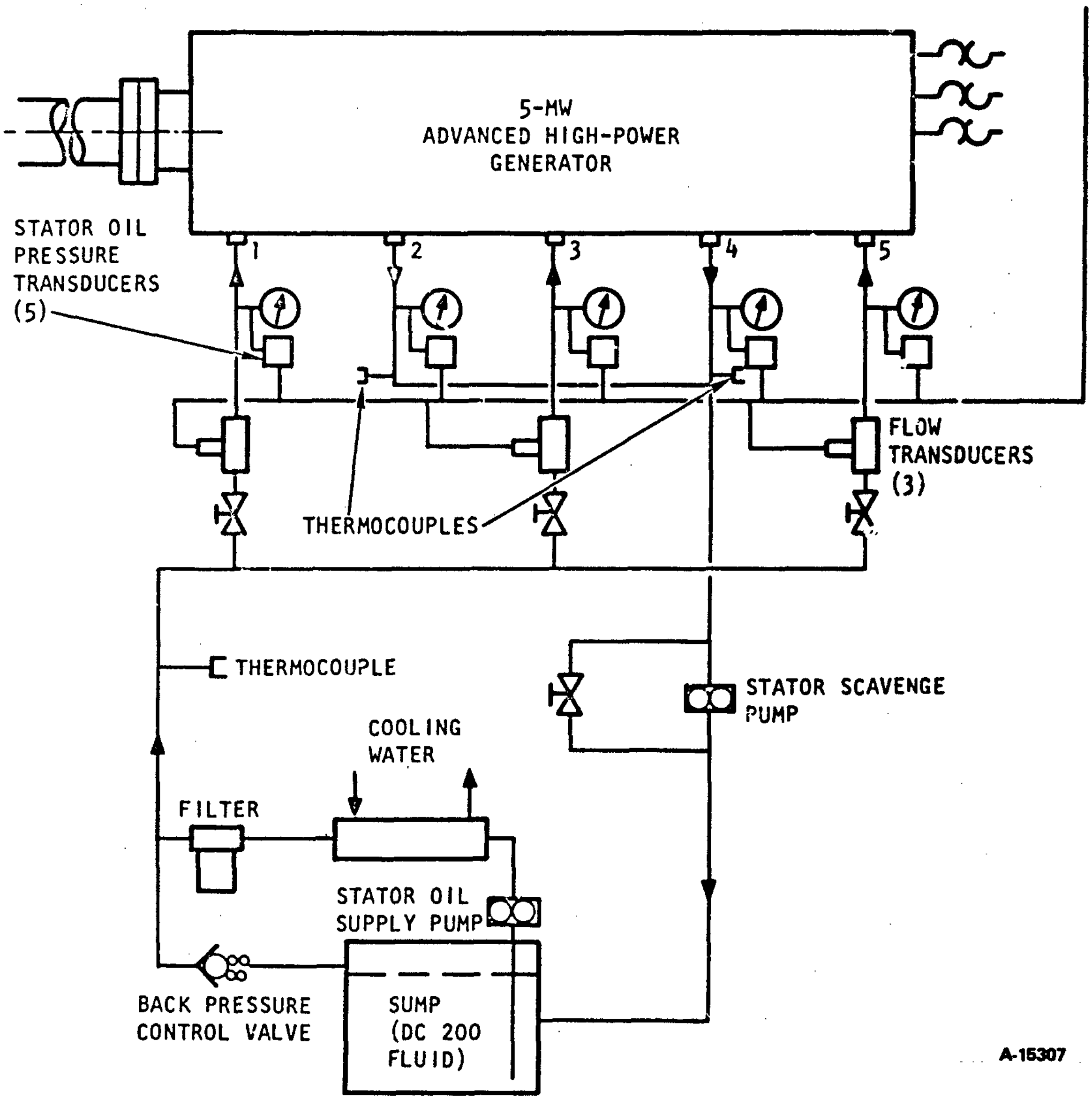


Figure 2-2. Stator Cooling System

2.2.2.1 Pump Power Requirements:

Power requirements for the pumps are as follows:

Parameter	Requirement
Supply	230 to 460 vac, 3-phase, 60 Hz, 1 hp
Scavenge	230 to 460 vac, 3-phase, 60 Hz, 3 hp

TABLE 2-2

STATOR OPERATING PARAMETERS

Parameter	Requirement
Oil	Dow Corning 200
Oil Flow	
Inlet No. 1, gpm	6.25
Inlet No. 3, gpm	12.5
Inlet No. 5, gpm	6.25
Total, gpm	25.0
Outlet No. 2, gpm	12.5
Outlet No. 4, gpm	12.5
Pressure	
Inlet, psia	19
Outlet, psia	7
Temperature	
Inlet, °F	120
Outlet, °F	To 250
Filtration, μ	25
Sump capacity, gal	50
Ultimate heat sink	CRF cooling tower water at TBD Btu/hr rate

2.2.2.2 Accessories

One level sight gage and five mechanical pressure gages are required.

2.2.2.3 Instrumentation

Instrumentation is required as follows:

Parameter	Requirement
Flow	Inlet transducers 0 to 6.25 gpm (2) 0 to 12.5 gpm (1)
Pressure	Inlet transducers (psia) (3) Outlet transducers (psia) (2)
Temperature	Inlet thermocouple (1) Outlet thermocouples (2)

2.2.2.4 Alarms

Alarm requirements are the following:

Parameter	Requirement
High outlet temperature	2
Low oil flow	3

2.2.3 Bearings

The rotor bearings will be cooled and lubricated by a system providing air-oil mist under pressure (see Figure 2-3).

Operating parameters are shown in Table 2-3.

2.2.3.1 Instrumentation

Instrumentation requirements are the following:

Parameter	Requirement
Pressure	Inlet transducer (psia) (1)
Temperature	Inlet thermocouple (1) Outlet thermocouples (2)

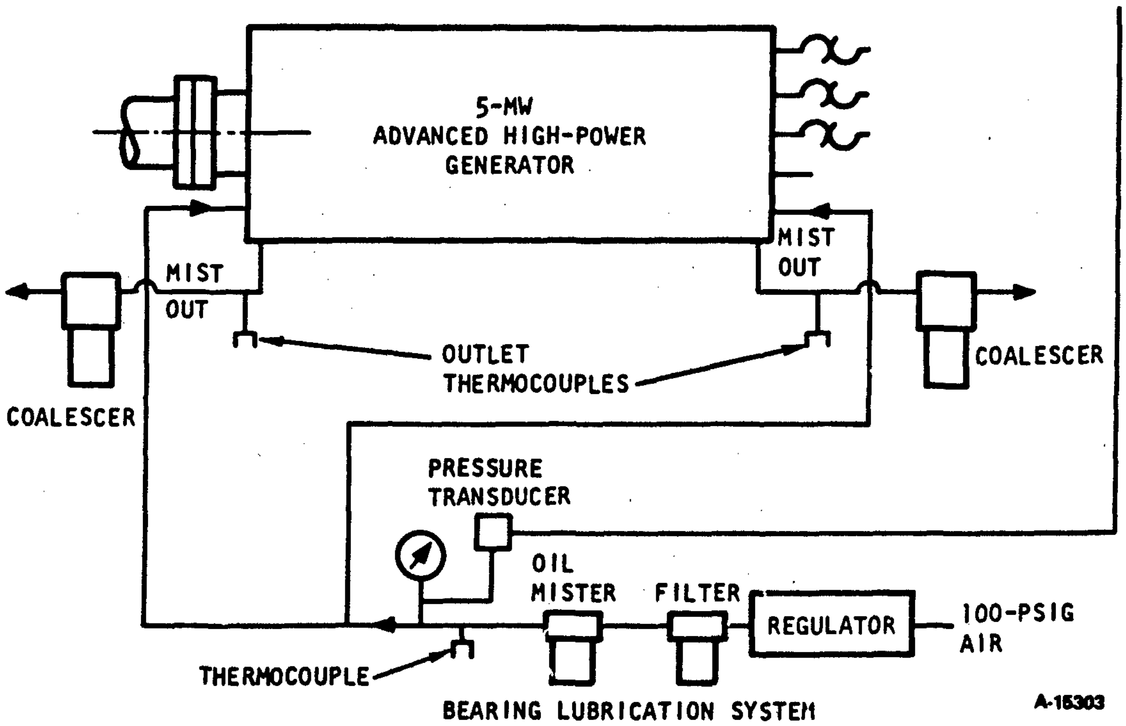


Figure 2-3. Bearing Cooling and Lubrication System

2.2.3.2 Alarms

Alarm requirements are the following:

Parameter	Requirement
High outlet temperature	2

2.2.4 Rectifier

The 3-phase bridge rectifier will be convection cooled by the CRF test article cooling system that circulates air inside the test chamber at 15,700 scfm and 100°F maximum temperature.

2.2.5 Water-Cooled Load

The load bank will consist of a submerged conductor tapped resistor array. Cooling will utilize the latent heat of vaporization of water primarily, plus convection.

TABLE 2-3

BEARING OPERATING PARAMETERS

Parameter	Requirement
Oil	Mobile Jet II (MIL-L-23699)
Flow	
Air, lb/min	0.045
Oil	TBD
Pressure	
Inlet, psia	15.3
Outlet	Ambient
Temperature	
Inlet	Ambient
Outlet	TBD
Filtration, μ	10
Sump capacity, oz	10

2.3 MECHANICAL DRIVE SYSTEM REQUIREMENTS

The 5-Mw advanced high-power generator and support/shield will be installed in the test chamber with attach points at the bulkhead and the front mount plate (see Figure 2-4).

The generator will be driven by the high- or low-speed motor in combination with high-speed gearbox 3 (refer to Figure 2-5). This drive system will provide the necessary power over a speed range from 2,000 to 18,000 rpm (Figure 2-6).

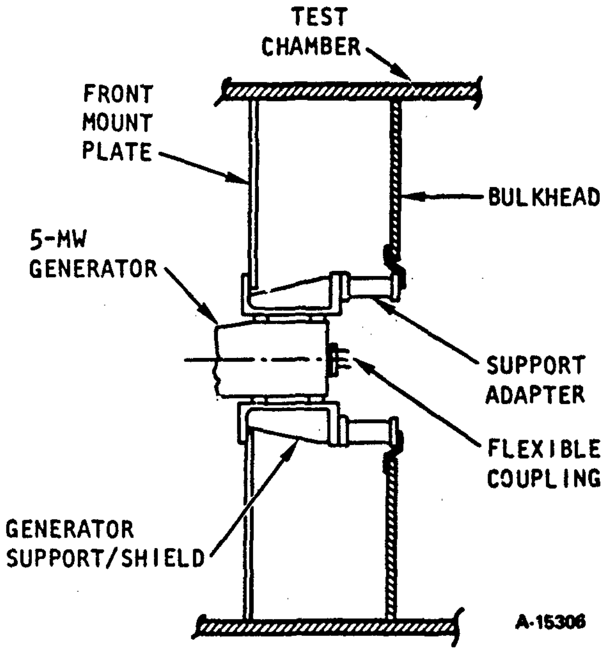


Figure 2-4. Generator Mounting

2.3.1 Power Requirements

Horsepower and torque requirements are estimated below.

Generator input hp

$$\frac{5 \times 10^6 \text{ w}}{746 \text{ w/hp} \times 0.96 \text{ eff}} = 6982 \text{ hp}$$

Generator input torque

$$\frac{6982 \text{ hp} * 33{,}000 \text{ lb-ft/min./hp}}{2\pi * 18{,}000 \text{ rpm}} = 2037 \text{ lb-ft}$$

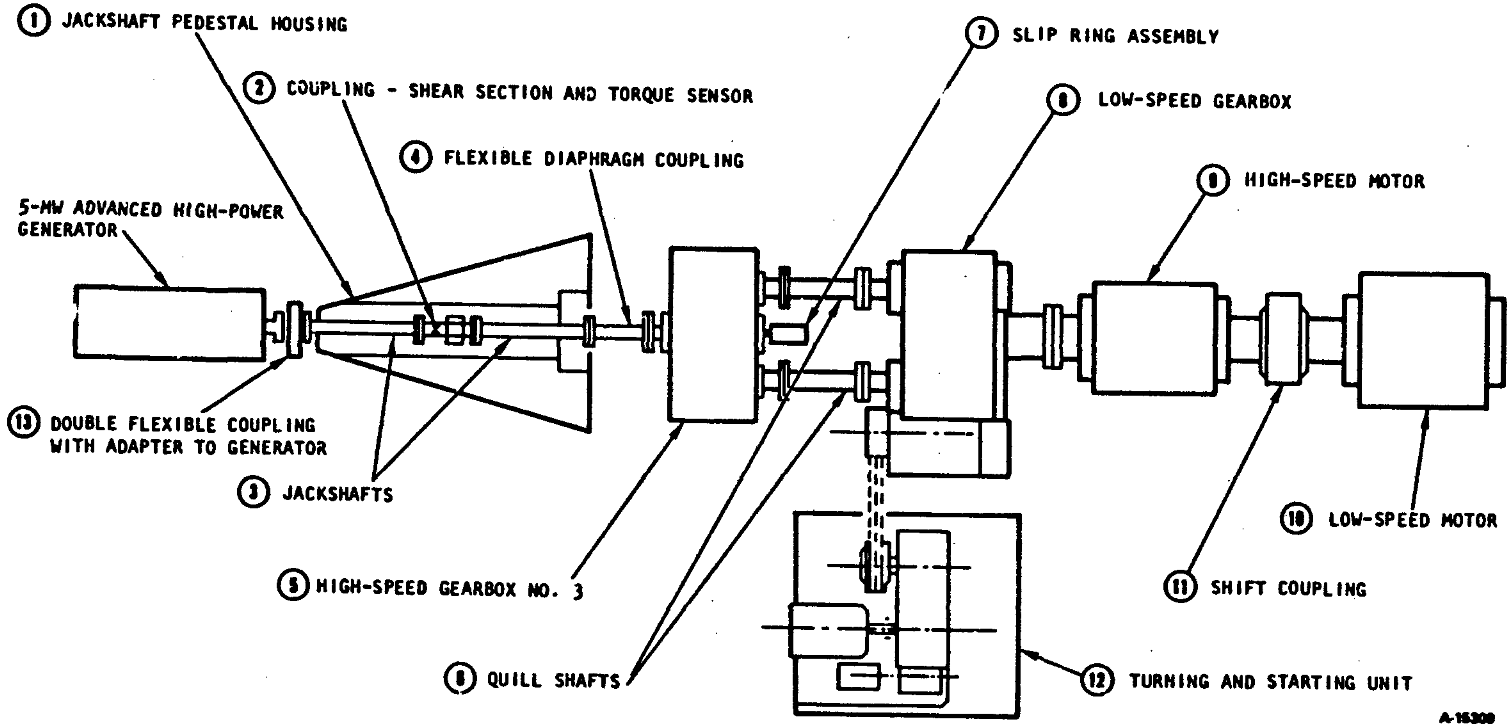


Figure 2-5. Mechanical Drive System

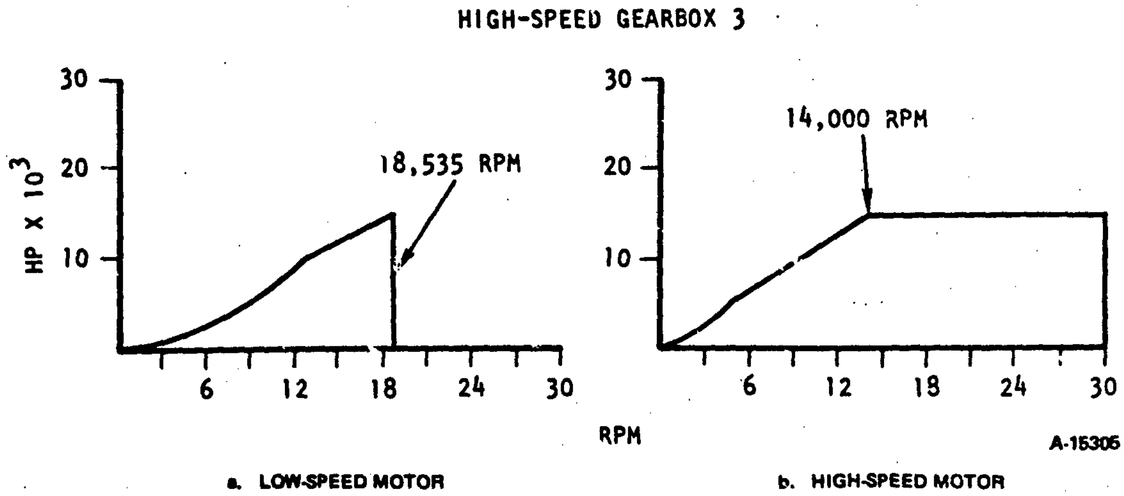


Figure 2-6. CRF Power/Speed Range

2.3.2 Special Drive System Components Required for Testing

Special drive system components required for testing are:

Item No. From Figure 2-5		Requirement
13	a.	Adaptor, generator to flexible diaphragm coupling
	b.	Double flexible diaphragm coupling
2	a.	Torque sensor, range to provide usable sensitivity at 2037 lb-ft
	b.	Shear section, to provide protection for torque sensor and generator, not to exceed 2240 lb-ft

2.3.4 Existing Drive System Components Required for Testing

Existing drive system components required for testing are listed in Table 2-4. Component numbering corresponds to the numbering in Figure 2-5.

A drive system analysis will be required to examine thoroughly the compatibility between the generator and CRF drive with respect to axial, radial, and torsional excitation frequencies.

2.4 INSTRUMENTATION REQUIREMENTS

Table 2-5 provides a preliminary list of the instrumentation needed for generator testing.

TABLE 2-4

EXISTING DRIVE SYSTEM COMPONENTS
REQUIRED FOR TESTING

Item No. From Figure 2-5 (Component)	Requirement
1 (Jack shaft pedestal housing)	Standard installation
3 (Jack shafts)	High speed Per CRF Dwg. 78-M10-0053 Speed range, 16,000 to 30,000 rpm
4 (Flexible diaphragm coupling)	Condition 3 Per CRF Dwg. EDS-76-M10-0006 Speed range 16,242 to 17,820 rpm Torque max. 58,205 lb-in.
5 (High-speed gearbox No. 3)	Speed range to 30,000 rpm Ratio, 7.8125 to 1
6 (Quill shafts)	Standard installation
7 (Slip ring assembly)	For transmission of up to ten two-wire thermocouple channels at 18,000 rpm
8 (Low-speed gearbox)	Standard installation Ratio 3.4896 to 1
9 (High-speed motor)	Standard installation 30,000 hp
10 (Low-speed motor)	Standard installation 30,000 hp
11 (Shift coupling)	Standard installation
12 (Turning and starting units)	Standard installation

2.5 ELECTRICAL CONNECTION AND LOAD REQUIREMENTS

The electrical system diagram, Figure 2-7, provides a schematic of the generator connection and a component layout corresponding to the items listed in Table 2-6.

TABLE 2-5

INSTRUMENTATION REQUIRED FOR GENERATOR TESTING

Component or System	Measurement	Sensor Type	Quantity	Alarm	Automatic Shutdown
Rotor	Temperature rotating, °F	T	10	High temperature (5)	No
Stator	Temperature in conductors and housing, °F	T	12	High temperature (6)	No
	Vibration in drive end	TBD	2	High vibration (2)	Excessive vibration (2)
	Vibration in non-drive end	TBD	2	High vibration (2)	Excessive vibration (2)
Rotor cooling	Air inlet temperature, °F	T	2	No	No
	Air outlet temperature, °F	T	2	High temperature (2)	No
	Air inlet static pressure,	TBD	1	No	No
	Static and delta pressure in airflow measuring section	TBD	2	Low flow	No
Stator cooling	Oil inlet temperature, °F	T	1	No	No
	Oil outlet temperature, °F	T	2	High temperature (2)	No
	Oil inlet pressure, 0 to 25 psia	Strain gage	3	No	No
	Oil outlet pressure, 0 to 25 psia	Strain gage	2	No	No
	Oil flow, 0 to 15 gpm	Turbine	3	Low flow (3)	No
Bearings	Mist inlet temperature, °F	T	1	No	No
	Mist outlet temperature, °F	T	2	High temperature (2)	No
	Mist inlet pressure, psig	Strain gage	1	Low pressure (1)	No
Drive	Speed, rpm	Monopole	1	No	Excessive rpm above set point
	Torque	TBD	1	No	Excessive torque
Electrical	Phase balance	AiResearch special test equipment	1	Phase imbalance	Phase imbalance
	Dc voltage	TBD	1	No	No
	Dc current	Millivolt shunt	1	No	No
	Dc breaker position	Auxiliary contacts	1	No	No
	Load control contactor position	Auxiliary contacts	8	No	No

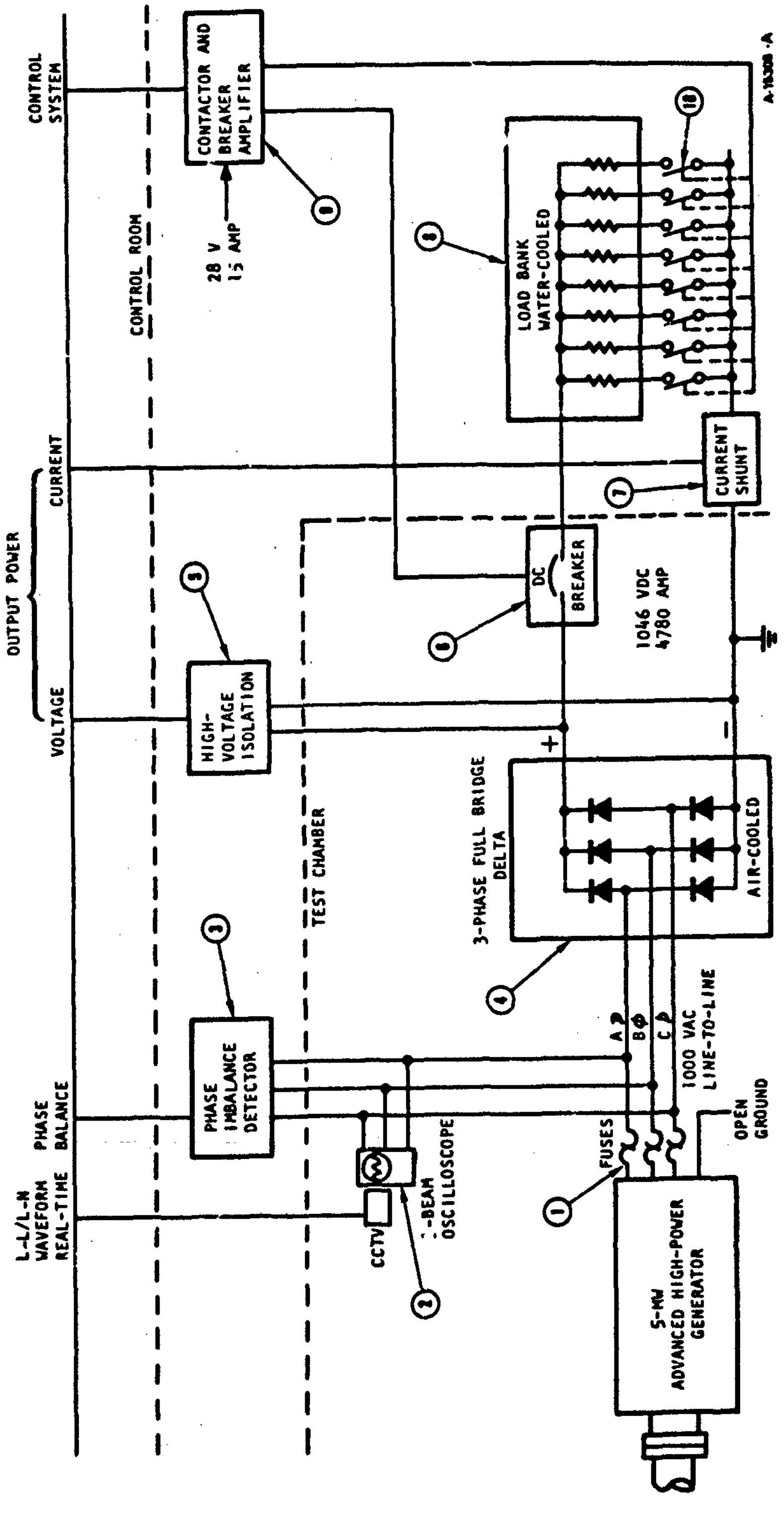


Figure 2-7. Electrical System Diagram

TABLE 2-6

ELECTRICAL CONNECTION AND LOAD REQUIREMENTS

Item No. From Figure 2-7 (Component)	Requirement
1 (Fuzes)	Manufacturer, J. Shanut Rated voltage, 2000 Rated amperage, 5000 Quantity, 3; 1 per phase
2 (Oscilloscope, three beam, and closed-circuit television camera)	Allows real-time viewing of 3-phase voltage without the capacitance effects of a 500-ft cable run to control room.
3 (Phase imbalance detector) (AiResearch special test equipment)	This device will provide a signal for dc breaker opening and rotation shutdown in the event of an unbalanced generator load. This condition might result from a single phase short or open circuit, internal or external to the generator.
4 (Rectifier, 3-phase delta-connected)	Manufacturer, PSI Inc., PN JD2300-40 Rating, 1500 vac, 2500 Hz, 5000 amp Cooling, convection air cooled
5 (High-voltage isolation)	Provides voltage scaling and isolation for the data acquisition system.
6 (Dc breaker)	Provides primary control of generator load Manufacturer, Siemens Rating, 1500 vdc 5000 amp Includes overcurrent trip Power required, 28 vdc at 5 amp
7 (Current shunt)	Manufacturer, Empro, Inc. P. O. Box 26064 Indianapolis, IN 46226 Model, WT-5000-50 Rating, 5000 amp at 50 mv output to data system
8 (Load bank)	The load will consist of an array of eight equal resistors each composed of nicrome ribbon of high surface-to-cross-section area. The resistors will be in turn connected across the output of the rectifier in parallel by dc contactors. This will provide an eight-step generator load zero to 5 Mw at full rotational speed of 18,000 rpm. The total resistor assembly will be submerged under water in a tank made of nonconducting material. The tank may require a water makeup system if high-load testing is conducted for extended periods.

TABLE 2-6 (Continued)

Item No. From Figure 2-7 (Component)	Requirement
9 (Contactor and breaker amplifier)	Provides power amplification from control system to dc breaker and eight load-control contactors. Input, low-level signal from control system Input power, as required Output, 28 vdc at up to 15 amp
10 (Load control contactors)	Manufacturer, Cutler Hammer Rating, 1000 amp, 1000 vdc Power required, 28 vdc at 1.2 amp

3. TEST DATA ACQUISITION

Exhibit 3A contains a description of the high-speed data acquisition system that will be utilized for all generator testing.

The selection of interface equipment, cabling, signal conditioning, and programming necessary for data system use will be the responsibility of CRF personnel. The thermocouples installed in the rotor and stator will be the only instrumentation provided with the generator at the time of shipment to the CRF.

EXHIBIT 3A

HIGH-SPEED DATA ACQUISITION SYSTEM

HIGH SPEED DATA ACQUISITION SYSTEM

(HPDAS)

1. This multi-channel, high performance data acquisition system consists of the following:

- 475 channels of digital data
- 48 channels of recorded analog data
- 12 channels for use by other systems
- 5 frequency-to-voltage converters

2. Component Breakdown:

- 391 Preston Scientific Model #8800 Universal Signal Conditioners; supplies excitation voltage, bridge balance, calibration, and signal return circuitry for various types of pressure and position transducers.
- 144 Preston Scientific Model #8800 Thermcouple Signal Conditioners; provides calibration and signal return circuitry for thermcouple and EMF signals.
- 5 VIDAR Model #323 frequency-to-voltage converters.
- 535 Preston Scientific Model #8300-XWBRC Amplifiers; each with computer controllable gain and filter selection; the filters are low pass, 3 pole filters and have the following cutoff frequencies: 10 Hz, 40 Hz, 120 Hz, 400 Hz, 1200 Hz and 4 wide band 100 KHz. The gains result in full scales of ±5, ±10, ±20, ±40, ±160, ±1250 and ±5120 millivolts.

A. 321 high performance amplifiers; no special options.

B. 104 high performance amplifiers; with a dual output capability.

C. 50 high performance amplifiers; with a linear overload capability to linearly handle an analog voltage up to five (5) times the maximum rated input.

D. 48 AC/DC amplifiers; converts AC signals from strain gages or other dynamic sensors into a DC analog voltage.

E. 12 moderate performance amplifiers; with no special options has a narrower bandwidth than the high performance.

- One 512 channel differential multiplexer

- One analog-to-digital converter with a conversion rate of 100 KHz

- 100 sample-and-hold circuits; for precise time correlation of data; S&H acquires data for the first 100 channels simultaneously and has a time displacement of 100 nano-seconds between any two channels.

3. Data System Performance:

- Overall system accuracy of 0.1% FS output.

- Throughput rate of 100,000 samples/second.

- A channel check subsystem is provided for on-line calibrations of the amplifiers to maintain the accuracy of this data system.

4. FM Playback System

- This system is also part of the HPDAS and consists of 48 channels of test article data monitored by small oscilloscopes. The main function of this system is to record, via four analog tape drives, high speed transient signals which can then be played back at slower speeds, amplified, multiplexed, and digitized. This information is then passed on to the main computer for data reduction via the DAC and the AUX computers.

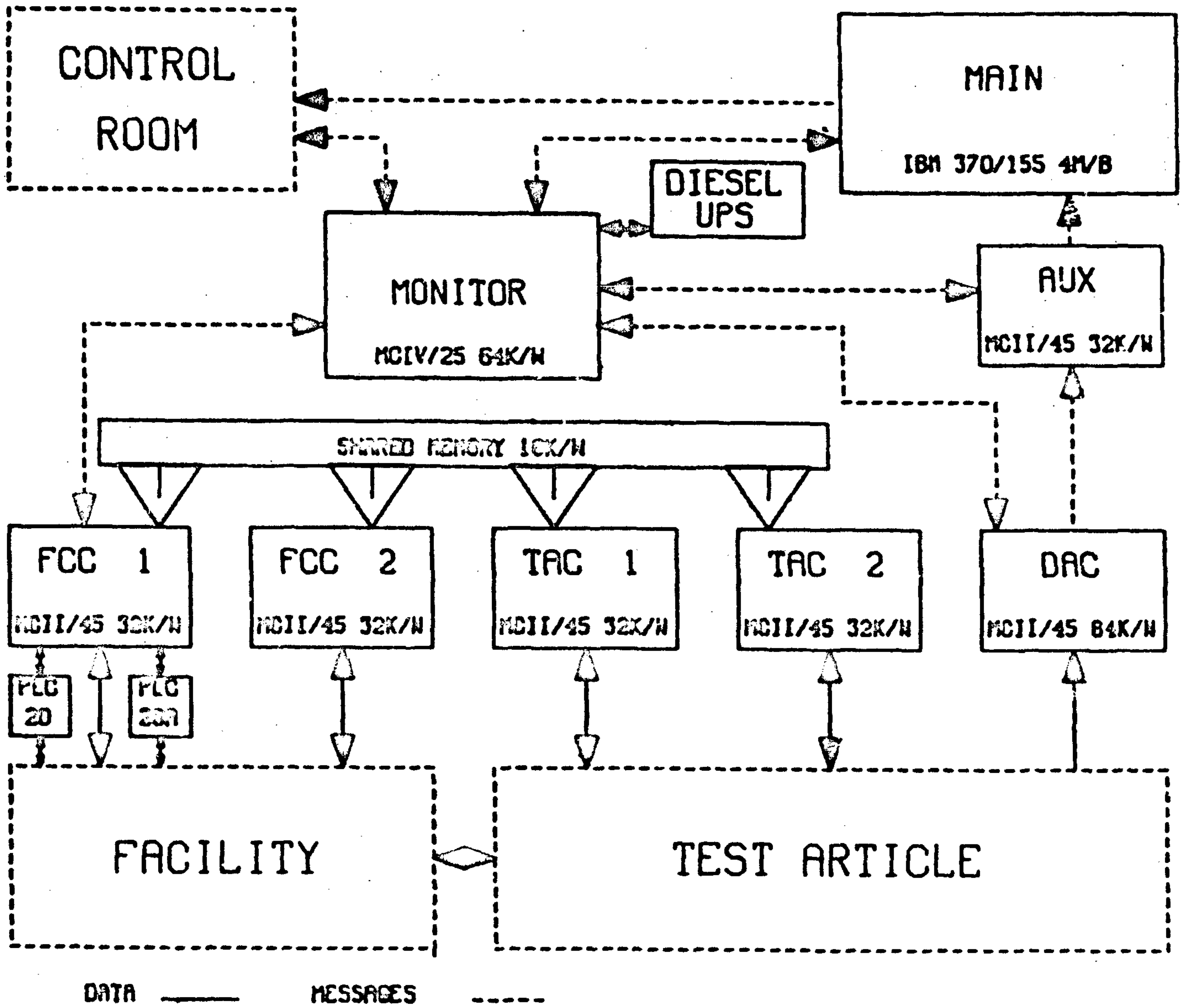
COMPUTER POWER

COMPUTER(s)	MAIN FUNCTION(s)	FEATURES
Test Article Control (TAC 1 and TAC 2) 2 - MODCOMP II/45	- Provides automatic control of the CRF inlet valves, test article discharge valves and test article variable geometry items such as stator vanes and stage bleeds.	- 32K of Private core memory (each) - 16K of shared memory - Adds 880 alphanumeric CRT console device (each) - 2.6 Mbyte removable cartridge disk drive (each)
Facility Control (FCC1 and FCC2) 2 - MODCOMP II/45	- Acquires Facility Data, drive system data and time data - Controls Drive System operation - Controls message traffic between the monitor computer and TAC 1, TAC 2, FCC1 and FCC2 computers.	- 32K of private core memory (each) - 16K of shared memory - Adds 880 alphanumeric CRT console device (each) - 2.6 Mbyte removable cartridge disk drive (each)
Monitor MODCOMP IV/25	- Operator-Facility Interface - Drives RAMTEK real time graphic displays, console switches and lights - Accepts and executes test segment displays - Central communications computer	- 64K of private core memory - 2.6 Mbyte removable cartridge disk drive - Adds 880 alphanumeric CRF console device - Two 4411 Card Readers - Three 9 TRK Tape Drives - One ISS Disk Drive - One Tektronix 4010-1 CRT Console Device

COMPUTER POWER (Cont'd)

COMPUTER(s)	MAIN FUNCTION(s)	FEATURES
Auxiliary (AUX) MODCOMP II/45	- Transfers data from the DAC computer to the main computer for data reduction	- 32K memory
Data Acquisition (DAC) MODCOMP II/45	- Acquires test article data - Executes transducer calibrabrations	- 64K of private core memory - 2.6 Mbyte removable cartridge disk drive - 4214 line printer - Adds 880 alphanumeric CRT console device - One 9 TRK tape drive - One 1403 line printer
Main IBM 370/155	- Data Reduction, on-line and and post processing - Drives 2250 real time graphic displays	- 4M byte of private core memory - 4 Intel 3330 disk drives - 3 STC 9 TRK 1600/ 6250 tape drives - 1 STC 9 TRK 800/ 1600 tape drive - Ten 3277 alphanumeric CRT console devices - Two 2250 IBM graphics - One electrostatic Gould plotter

COMPUTER CONFIGURATION



ON-LINE DATA REDUCTION

Two independently operated IBM 2250 Vector Graphic CRTs allow engineers to organize and graphically present either real-time or post processed test data. There are three modes of operation, i.e., static, transient and monitor. Data taken in the static mode is used to generate map, profile and X vs Y type displays. Data taken in the transient and monitor mode is used to generate transient type displays.

Four types of engineering displays are available:

1) Compressor Rigs
2) Profiles
3) X versus Y1, Y2, Y3, Y4
4) Transient Displays

Typical Displays are:

1) Pressure ratio vs % corrected flow (Map)
2) Compressor efficiency vs % corrected speed (X vs Y)
3) Wall static pressure vs axial location (Profile)
4) Stage pressure ratio vs % corr flow (X vs Y)
5) Stage efficiency vs % corr flow (X vs Y)

A light pen is used on the 2250 graphics for quick selection of mode and definition of displays.

Off-Line Data Reduction

Consists of various printouts and graphics from the IBM 370/155 and playback from the FM analog recording system.

4. TEST CONDUCT

The various tests outlined in the procedures that follow will be used to determine the actual operating characteristics of the 5-Mw generator.

The operating characteristics of the advanced high-power generator as specified in the Air Force statement of work (Section F, para. 4.6.1, F33615-76-C-2168) include the following important requirements:

Parameter	Specification
Output power	5 Mw
Specific weight	0.1 lb/kw
Efficiency	95 percent or greater

4.1 NO-LOAD TEST

4.1.1 Scope

The no-load test entails measuring no-load phase voltages at 2,000, 4,000, 6,000, 8,000, 10,000, 12,000 14,000, 16,000 and 18,000 rpm and the input torque at these points.

4.1.2 Objective

The objective of the no-load test is to determine the no-load losses from the input torque measurement and the no-load operating point between 2,000 and 18,000 rpm.

4.1.3 Procedure

Settings	Procedure
1. Rotor, stator, and bearing cooling systems, ON	3. Drive generator at 2000 rpm
	4. Measure phase A, B, and C peak-to-peak voltages on oscilloscope; measure rpm and drive torque.
2. Dc breaker, OPEN	5. Increase speed by 2000 rpm and take measurements of step 4.
	6. Repeat steps 4 and 5 until 18,000-rpm point is reached.
	7. Calculate the maximum difference between phase peak-to-peak voltages.

The input torque will be proportional to the generator's no-load losses.

4.2 LOAD TEST

4.2.1 Scope

The load test entails measuring a set of output voltages and currents at 18,000 and 9,000 rpm.

4.2.2 Objective

The objective of the load test is to develop in graph form the voltage-versus-current characteristics of the 5-Mw generator and determine its operating efficiency.

4.2.3 Procedure

The load test is conducted as described below.

Settings	Procedure
1. Rotor, stator, and bearing cooling systems, ON	3. Drive generator according to test 1 of Table 4-1.
	4. Measure dc voltage and current, rpm, and input torque.
2. Dc breaker, CLOSED	5. Repeat steps 3 and 4 until all the tests listed in Table 4-1 have been run.
	6. Calculate the efficiency from input torque and output power measurements
	7. Plot dc voltage versus dc current at 18,000 and 9,000 rpm.

4.3 COMMUTATING REACTANCE TEST

4.3.1 Scope

The commutating reactance test entails measuring rpm and dc voltage and current and obtaining an oscillograph of the line-to-neutral voltage at the 5-Mw, 18,000-rpm point.

4.3.2 Objective

The objective of the commutating reactance test is to determine the commutating reactance of the generator and the time required to complete commutation.

TABLE 4-1

SEQUENCE OF LOAD TESTS

Test No.	Revolutions per Minute	Load-Bank Sections	Resistance, Ω	Dissipative Power, kw
1	9,000	1	1.751	156.2
2	9,000	2	0.876	312.4
3	9,000	3	0.584	468.4
4	9,000	4	0.438	624.8
5	9,000	5	0.350	781.0
6	9,000	6	0.292	937.2
7	9,000	7	0.250	1,093.5
8	9,000	8	0.219	1,249.7
9	18,000	1	1.751	624.8
10	18,000	2	0.876	1,249.0
11	18,000	3	0.584	1,873.4
12	18,000	4	0.438	2,498.0
13	18,000	5	0.350	3,126.0
14	18,000	6	0.292	3,746.9
15	18,000	7	0.250	4,374.0
16	18,000	8	0.219	5,000.0

4.3.3 Procedure

The test is conducted as described below.

Settings

1. Rotor, stator and bearing cooling systems, ON
2. Dc breaker, CLOSED
3. All eight load switches, CLOSED

Procedure

4. Adjust the oscilloscope to display one cycle of line-to-line voltage.
5. Drive the generator to 18,000 rpm, 5 Mw.
6. Record dc voltage and current and rpm.
7. Photograph oscilloscope waveform.

The commutation angle (μ) is calculated by measuring the duration of the line-to-line zero voltage and comparing it to the overall duration. The commutating reactance is calculated using the following equation:

$$X_{com}\ (\Omega) = (\cos \mu - 1)\frac{\sqrt{1.5} * V_{LNO}\ (rms)}{I_{DC}}$$

where

V_{LNO} is the line-to-neutral rms open-circuit voltage, which is calculated from the oscilloscope picture of the rectified line-to-line voltage

and

$$V_{LNO}\ (rms) = \frac{V_{LLO}\ (peak)}{\sqrt{6}}$$

$$V_{LLO}\ (peak) = (V(60\ deg) + I_{DC} * 2 * R_o)/\sin 60\ deg$$

where

V(60 deg) is the instantaneous voltage, line-to-line, at 60 deg on the oscilloscope picture

I_{DC} is the measured dc current

R_o is the phase resistance of the generator

5. SYSTEM SAFETY/HAZARD ANALYSIS

A preliminary hazard analysis has been completed for the advanced high-power generator test. All hazards found appeared to be adequately controlled except that of dropping the generator during installation. Extreme care should be exercised in lifting the generator since no dedicated attachment points have been provided. This document supplements AiResearch Report 80-17402.

5.1 ANALYSIS

The preliminary hazard analysis for the advanced high-power generator test is contained in Table 5-1. Column 1 of the table lists the hazardous conditions that are or may be present during testing or installation of the generator. The possible causes of these conditions are listed in Column 2. The third column lists the possible effects of the hazardous condition. Hazard levels were assigned to the hazardous condition effects per MIL-STD-882A categorized as follows:

Hazard Category Classification	Description
I (Catastrophic)	May cause death of personnel or loss of generator or test facility (unrepairable).
II (Critical)	May cause severe injury to personnel or major damage to generator or to test facility (repairable).
III (Marginal)	May cause minor injury to personnel or minor generator or test facility damage.
IV (Negligible)	Will not result in injury to personnel or damage to the generator or to the test facility.

These hazard levels are applied in the fourth column of Table 5-1. The last column lists recommended corrective action and describes the protective features of the generator and test facility.

5.2 CONCLUSIONS AND RECOMMENDATIONS

There are four Category II hazards, four Category III hazards, and one Category IV hazard associated with the installation and testing of the advanced high-power generator. Adequate protection has been provided against all hazards except those associated with lifting the generator. Special care must be taken to prevent damage to the generator or injury to personnel when the unit is moved.

TABLE 5-1

PRELIMINARY HAZARD ANALYSIS

AREA OR SYSTEM ADVANCED HIGH POWER GENERATOR TEST

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DISCUSSION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
Bearing Seizure	1. Contamination of bearing. 2. Foreign material between rotor and housing. 3. Loss of bearing lubrication.	1. Large inertia loads leading to possible fracture of fixture mounts and freed rotor/housing assembly.	II	1. Bearings are ABEC 7 quality with oil spray lubrication. 2. Personnel will not be permitted in the test chamber during testing. 3. Test fixture will be designed to hold the generator in the event of rotor lock up at maximum speed.
Large Mass Of Generator	1. Absence of lifting provisions allows generator to be dropped during transportation or installation.	1. Possible fracture of generator parts. 2. Possible injury to personnel moving the generator.	III	Appropriate provisions should be made to enable safe movement of the generator, e.g., lifting eyelets.
Rotor Overspeed	1. Generator loses its load. 2. Test equipment malfunction.	1. Possible rotor burst, releasing fragments of steel into the test chamber.	II	1. Shaft speed is instrumented. Test fixture contains provisions for emergency shutdown in case of overspeed. 2. Shields are provided to contain fragments to the test facility. 3. No personnel will be permitted in facility during testing.

TABLE 5-1 (Continued—Page 2 of 3)

AREA OR SYSTEM ADVANCED HIGH POWER GENERATOR TEST

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DISCUSSION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
Fire	1. Bearing overheat from contamination or too much oil during operation. 2. MC 200 cooling oil ignitor (flash point 175°F, Autoignition Temp. 806°F). a) From overheat. b) From electrical spark.	1. Possible injury to personnel or equipment damage.	III	1. Oil/air mister should filter oil. 2. Facility is equipped with fire detection and 4 tons of 300 psig CO_2 for total flooding extinguishment. 3. Inlet & outlet oil/air mixture pressure and temperature will be monitored and alarm will sound if temperature is excessive or pressure is too low. 4. Outlet cooling oil temperature will be monitored and alarm will sound if temperature becomes excessive.
High Voltage	1. Exposed terminals may come into contact with personnel or equipment.	1. Possible injury to personnel or or equipment damage.	IV	1. Personnel will not be in vicinity when when test is in progress. 2. An insulating cover will be provided.
Static Electricity	1. Buildup during test due to improper grounding.	1. May cause personnel injury, equipment damage or initiate a fire.	III	1. Generator will be grounded during test by bolting to the test fixture.
Excessive Vibration	1. Bearing failure. 2. Bearing support failure. 3. Rotor imbalance due to internal fracture.	1. Damage to generator and test equipment; may lead to fatigue failure of generator parts.	II	1. Test fixture contains provisions for quick shutdown in case of excessive vibration. 2. Bearings are resilient-mounted. 3. Structural integrity has been verified by rotor test & stress analysis.

TABLE 5-1 (Continued--Page 3 of 3)

AREA OR SYSTEM ADVANCED HIGH POWER GENERATOR TEST

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DISCUSSION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
Excessive Torque at Shaft	1. Malfunction of test equipment. 2. Bearing failure. 3. Rotor becomes locked with stator.	1. Possible overstress of generator parts; e.g., windings, shaft or bearing.	II	1. Torque sensor is provided on the input shaft; alarm will sound if torque is excessive.
Short Circuit	1. Damaged winding. 2. Misconnection of windings.	1. Loss of load. 2. Overheated windings. 3. Fire.	III	1. Phase balance is sensed and there will be quick shutdown if unbalance is excessive.